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T. RIDER, Acting Government Printer, Melbourne.

[Proc. Roy. Soc. Victoria, **51** (N.S.), Pt. I., 1938.]

Art. I.—*Studies on the Australian Clavariaceae.*

Part I.

By STELLA G. M. FAWCETT.

[Read 16th December, 1937; issued separately, 23rd January, 1939.]

The plants comprising the family Clavariaceae are commonly known as coral-fungi, taking their name from the larger and more spectacular members, but there are many smaller plants included in the family, which bear no resemblance to coral, and which are more accurately described by the name *Clavaria* (L. clava, a club).

The family Clavariaceae at present includes the following genera: *Clavaria, Typhula, Pistillaria, Lachnocladium, Pterula* and *Physalacria.* (*Myxomycidium*, long held to be of this family, has been the subject of a paper by Linder (16) who places the genus in the Vuilleminiaceae. The issue is complicated, and will be discussed later, but it is necessary to say that at least two of the premises on which he based his assumption, have, by recent work on *Clavarias*, been shown to be false).

The family Clavariaceae has been fully described by Coker (7) who states that the hymenium is "more or les amphigenous."

In appearance and texture the family approaches the Thelephoraceae from which, in the past, its members were distinguished on grounds of texture and "a more or less amphigenous hymenium." Thus *Sparassis* was formerly included in the Clavariaceae. Engler and Prantl (10) give the position of the hymenium in the Clavariaceae as amphigenous. Although, in describing the family, Rea (19), says that the hymenium is "more or less amphigenous," there is nothing in the generic and specific descriptions of members of the family, to indicate that the hymenium is ever anything less than amphigenous. For instance, Rea states, p. 705, *Clavaria* "hymenium even, amphigenous," p. 720 *Typhula* "hymenium smooth, confined to the clavate portion of the receptacle," p. 722 *Pistillaria* "hymenium smooth, confined to the clavate portion of the receptacle," *Pterula* "hymenium smooth."

I have examined one species of *Pterula*, and the branches, although fine, were cylindrical, and the hymenium amphigenous. Rea (19) does not deal with *Lachnocladium*, but Coker (7), in defining the genus says, "hymenium covering the plant completely, except for the tomentose tips and sterile base."

Coker, in discussing *Physalacria*, states that the hymenium only occurs on the lower surface of the head. In Victorian plants, identified as *P. inflata*, the hymenium was found to cover completely the entire swollen part of the plant.

Thus there is strong evidence for the non-occurrence of dorsiventrality in the Clavariaceae, and I suggest that the amphigenous hymenium is characteristic of the family and serves to distinguish it from the Thelephoraceae.

At the present time the classification of the family is in a chaotic state, as the genera have been poorly defined and several of the definitive characters are of poor systematic value. For instance, differences in texture have been used to separate genera. The texture of a plant is difficult to define exactly, and although a number of plants in the family have indisputably tough, fleshy or waxy textures, difficulties arise when plants showing a texture intermediate between any two of these three are considered, and one finds all gradations between soft, fleshy, gelatinous and woody in this family.

In this account of the Clavariaceae, use has been made, as far as possible, of morphological features in the separation of genera and species.

Distribution and Habit of the Family.

The Clavariaceae is well distributed in temperate and tropical countries, and a few species occur in sub-arctic regions. While each area has a number of species which are peculiar to it, there are many such as *Clavaria botrytis* and *C. flava*, which are of world-wide occurrence. In temperate regions the fruiting periods are generally late autumn and early spring.

Although most members of the family appear to be unspecialized saprophytes, a large number grow only on decaying wood, and others require the decaying parts of specific plants for their growth. For instance *Pistillaria fulgida* Fr. (19) grows only on the dead stems of *Dipsacus pilosus* and *Helianthus tuberosus,* and a large group, including *C. gracilis* and *C. abietina*, will grow only on fallen leaves and twigs of Conifers.

There are a few parasites included in the family, chiefly species of *Typhula* e.g. *T. Itoana* Imai is a parasite on wheat and oats in Japan.

In spite of the apparently unspecialized food requirements of most of the family, attempts to grow them in culture have been unsuccessful, with one exception, *C. complanata* Clel., which grows well on 2 per cent. malt agar. It was thought that cultural characters might be of use in the classification of difficult species.

Tissue cultures were attempted with nine species of *Clavaria* on the following media: malt agar, honey agar, raisin agar; spores of the same nine species were sown on plates of the following media: malt agar, plain agar, sterile soil, honey agar, raisin agar, potato dextrose agar, sterile water, malt agar with lactic acid, and malt agar with sodium hydroxide. Freshly obtained and three months' old spores were used.

Varying temperatures had no effect. Cultures were incubated at 4°C., 23°C., and 30°C., and also at room temperature. In addition a suspension of spores *C. flava* in sterile water, was divided into six parts. Two parts were kept at room temperature, two parts were left in the open and the others were kept at 4°C. This preliminary treatment lasted for five weeks. Then one tube from each set of conditions was heated to 42°C. for ten minutes the others being kept as a control. After this treatment the six tubes were incubated at 30°C. Result: no germination in twenty-one days.

Keeping the cultures in complete darkness had no effect. Digestion experiments were also tried. Three malt agar plates were sown with spores of *C. corallino-rosacea*, and three more with spores of *C. fusiformis.* To the first plate of each kind 0.001 per cent. NaOH and trypsin was added, to the second 0.001 per cent. HCl. and pepsin, and the third plates were kept as controls. All were incubated at 35°C. for 21 days. No spores germinated.

Historical Survey.

Hitherto, accounts of the Australian Clavariaceae have been almost exclusively confined to the genus *Clavaria.* This is understandable as species of *Clavaria* are the most commonly seen. *C. Kalchbrenneri* was described by von Mueller (15) (not *C. Kalchbrenneri* Sacc.), and he sent many specimens to Cooke (8), who published these records together with descriptions of all the Australian species described before 1892. Since then McAlpine has described one species, *C. phyllophila* (17), and Rodway has listed a number of Tasmanian species. In "Records of Australian Fungi" (6), Cleland and Cheel discuss the occurrence and characters of several species recorded by Cooke. In 1931, Cleland (4) described eight new species, and, in a more recent publication (5) records sixteen species.

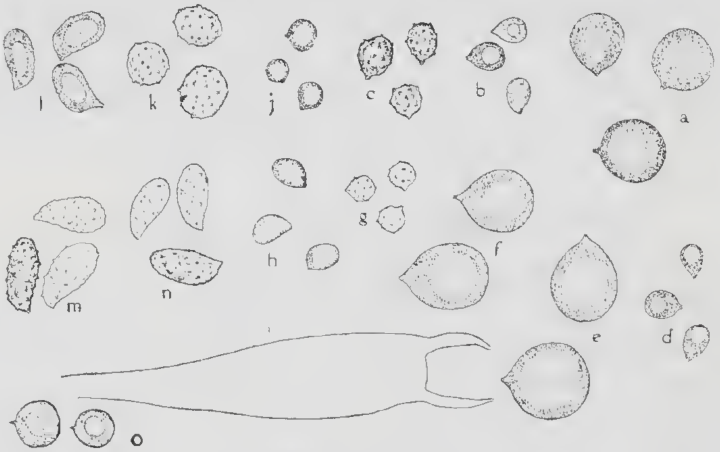
In 1932 McLennan (18) published an account of the common Victorian species of *Clavaria* to stimulate interest in them. Japanese work undertaken by Imai has some bearing on Australian studies in the group, as many species are common to both countries (11-14).

Genus **Clavaria** Vaill.

The most complete definition of the genus is that given by Coker (7). He says that the habit is "saprophytic, or in a few species saprophytically associated with algae." Since this description was published, one species, *C. Tochinaiana* Imai (11), has been described as a parasite of cabbage. Since the first description of the genus there have been many attempts to subdivide it. (For full discussion see Coker (7)). The classification devised by Fries, which has been in common use for many

years, has been amplified by Coker so that the genus is divided into eleven groups, which he considers are "of a validity at least equal to accepted genera of agarics and other families of fungi," but he states that "to distinguish sharply between such groups is, however, no easier than in most cases of splitting, and we are inclined to choose here a course that we should like to see much more generally followed, which is to let the old genera alone until it becomes a greater inconvenience to retain them than to separate them."

In this paper Coker's classification has been followed and groups 3, 4, 7, 8 and 9 of the genus are dealt with.



TEXT FIGURE 1.

Spores of the following species of *Clavaria:* (*a*) *C. muscoides.* (*b*) *C. subtilis.* (*c*) *C. Kunzei* (from specimen at National Herbarium, Melbourne, identified by Cooke). (*d*) *C. cinnamonea* (type). (*e*) *C. cristata.* (*f*) *C. vinacco-cervina* (part of co-type). (*g*) *C. Crocea.* (*h*) *C. umbrinella* and (*i*) basidium of *C. vinaceo-cervina* (part of co-type). Note the two large incurved sterigmata. Spores of: (*j*) *C. Bizzozeriana* (*k*) *C. pyxidata* var. *asperospora* (type). (*l*) *C. gracilis.* (*m*) *C. crispula.* (*n*) *C. stricta.* (*o*) *C. Nymaniana.* Magnification × 1125.

GROUP 3.

CLAVARIA MUSCOIDES Fr. ex L. Flora Suecica (2nd ed.), p. 457, 1755.

Plate 1., Figs. 1 and 2.

Clavaria fastigiata L. Flora Suecica (2nd ed.) p. 457, 1755.
Clavaria corniculata Schaeff. Fung. Bavar. pl. 173, 1763.
Clavaria pratensis Pers. Comm. p. 52 (183), 1797.
Clavaria furcata Pers. *Ibid.*, p. 52, 1797.
Clavaria vitellina Pk. Rept. N.Y. St. Mus., 43: 24, (70), 1890 (not *C. similis* Boud. and Pat.).
Clavaria Peckii Sacc. Syll. Fung. 9–249, 1891 (not *C. Peckii* Sacc. and D. Sacc.).
Clavaria helveola var. *dispar.* Pers. Myc. Europ. 1: 181, 1822.
Clavaria fellea Pk. Rept. N.Y. St. Mus., 51: 292, 1898.
Clavaria muscoides var. *obtusata* Britz. Hymen. Sudb., Clavariei, fig. 45, 1879–97.
Clavaria straminea Cotton. Trans. Brit. Myc. Soc. 3, 265, pl. 11, fig. D, 1909–10.

Plants of moderate size, 5-8 cm. high, rarely simple, most often antlered or branched two or three or four times, growing in clusters of two or three separate plants, occasionally forming a large mass in which the individual plants are fused at the base, more or less rooting. Stem long or short, of the same diameter as the branches which are usually between 2 and 3 mm. in diameter, branching irregularly dichotomous, axils open and rounded, much flattened below, branches elongated, cylindrical, smooth and flexuous, tapering bluntly to form entire tips. Colour of young plants Light Orange Yellow, of mature plants Cinnamon Buff at the tips, shading to Clay Colour at the base.

Texture when young, moderately brittle, in age, rather tough. Flesh rather translucent but the outside layers i.e. the hymenial and sub-hymenial layers, are very opaque. Taste and smell slight, but acrid and unpleasant; in age, a strong odour of ammonia develops.

Spores white in mass, smooth, globose, with an abrupt minute apiculus 5.6-8μ. Basidia 4-spored, sterigmata curved, about 7-8μ long.

Coker describes the colour of *C. muscoides* as "varying from rather pale dull yellow to deep clear yellow or ochraceous yellow shading downward to darker brown." Mature plants found in Victoria are much browner than this. But Coker regards *C. straminea* Cotton as a synonym of *C. muscoides*. He states "no differences of any importance between *C. straminea* and *C. muscoides* appear from Cotton's description of the former. Simple plants of *C. muscoides* are not at all rare in Victoria, and could hardly be better described than by Cotton's diagnosis for *C. straminea*." The Australian plants are straw-coloured like *C. straminea*. Very yellow specimens have not been collected here.

Cooke records *C. muscoides* for Victoria and New South Wales, spores 6μ diam. in pastures.

GROUP 4.

CLAVARIA CRISTATA Fr. ex Holmsk. Rolland, Champ. T 103, no. 230.

Plate 1, Figs. 3–5; Plate 2, Fig. 1; Text fig. 1, e.f.i.

Clavaria coralloides L. (in part) Fl. Suecica, 2nd ed., p. 457, 1755.

Clavaria albida Schaeff. Fung. Bavar. p. 116, pl. 170, 1763.

Clavaria laciniata Schaeff. *Ibid.*, p. 122, pl. 291, 1770.

Clavaria cinerea Bull. Herb. Fr. p. 204, pl. 354, 1787.

Clavaria rugosa Bull. *Ibid.*, p. 206, pl. 448, fig. 2, 1789 (not *C. rugosa* sensu Sowerby Engl. Fung. pl. 235).

Clavaria elegans Bolton, Hist. Fungi Halifax, p. 115, pl. 115, 1789.

Clavaria amethystea Bull. Herb. Fr. p. 200, pl. 496, fig. 2, 1790.

Clavaria cristata Holmsk. Beata ruris I: 92, pl. 23, 1790 (p. 97, Pers. ed. 1797).

Clavaria fimbriata Pers. N. Mag. Bot (Romer's) p. 117, 1794.

Clavaria trichopus Pers. Comm. p. 50 (182) pl. 4, fig. 3, 1797.

Clavaria palmata Pers. *Ibid.*, p. 45 (177) 1797.
Clavaria fallax Pers. *Ibid.*, p. 48 (180) 1797 (not *C. palmata* Scop.).
Clavaria grisea Pers. Comm. p. 44 (176) 1797.
Clavaria grossa Pers. *Ibid.*, p. 50 (182) 1797.
Clavaria macropus Pers. (sense of Fries and Bresadola) Comm. p. 51 (183) pl. 1, fig. 2, 1797.
Clavaria fuliginea Pers. Myc. Europ. 1, 166, 1822.
Clavaria alba Pers. *Ibid.*, 1, 161, 1822.
Clavaria cristata var. *curta* Junghuhn. Linnaea 5, 407, pl. 7, fig. *2b*, 1830.
Clavaria afflata Jagg. (sense of Bresadola) Flora 19 (1), 231, 1836.
Clavaria cristata var. *flexuosa* Junghuhn. Linnaea 5, 407, pl. 7, fig. *2a*, 1830.
Clavaria Krombholzii Fr. Epicr, p. 572, 1838.
Clavaria lilacina Fr. Hym. Eur. p. 667, 1874 (not *C. lilacina* Junghuhn).
Clavaria dichotoma Godey. in Gillet. Hym. Fr. p. 766, 1874.
Clavaria Schaefferi Sacc. Syll. Fung. 6, 693, 1888.
Clavaria sphaerospora E. & E. Journ. Mycol. 4, 62, 1888.
Clavaria sublilacina Karst. Finlands Basidsvampar p. 375, 1889.
Clavaria Favreae (Quel) Sacc. & Trav. Syll. Fung. 19, 231, 1910.
Clavaria Herveyi Pk. Rept. N.Y. St. Mus. 45, 84, 1892 (*rugosa* form).
Clavaria cinerea var. *gracilis* Rea. Trans. Brit. Myc. Soc. 6, 62, 1917.
Clavaria mutans Burt., Ann. Mo. Bot. Gard., 9, 31, pl. 6, fig. 41, 1922.
Clavaria histrix E. & E. Herbarium name.
Clavaria vinacceo cervina Clel. Trans. Roy. Soc. S.A., 1931.
Clavaria sub-rugosa Clel. *Ibid.*, p. 152-160.

Coker's description of *C. cristata* is as follows: "Remarkably variable in both form and colour. The typical form is whitish or pallid. Slender, narrow about 2-3 mm. thick below and 3-6 cm. high, long stalked with a few or several branches which are rather abruptly crested at the ends with small, pointed, more or less crowded branchlets; sometimes there is a single slender stalk with a dense crest at the tip, or there may be several stalks attached near the base and these may branch near the middle. Other forms besides the typical are included in the following notes. At times none of the branches is crested or some may be crested and others not; also the stem may be much flattened and expanded upwards, with a few irregular flat branches, or with no branches but rugose-wrinkled or knobbed. The tip is sometimes flattened and expanded like an antler, and in less complex forms the plants are apt to be somewhat enlarged and flattened upwards. Colour white at base and usually light-grayish flesh colour elsewhere, except the tips which are creamy white when young, then becoming coloured more like the branches and easily blackening after maturity. The colour varies from dull or creamy white to lavender gray (or with a tint of this colour with

tan), or smoky lavender pale to deep mouse gray, ash colour, drab or dull yellow, with all admixtures of these colours, surface even below, more or less channelled or wrinkled upwards. Flesh dry, toughish, not brittle, bending on itself without a complete break, creamy white, softer inside, and usually with one or two small uneven cavities in centre from separation of the fibres. odour almost none, taste mild, not very pleasant, bitterish, musty, at times a little like that of *Agaricus campestris.*

Spores when fresh, pure white, smooth, regular, sub-spherical to short elliptic, 5.2-7.4 x 7-9.2μ, after standing for some time they become yellowish and often irregular by collapsing. Basidia 2-spored in all forms, the long stout sterigmata usually curved inward. Hymenium thick 110-165μ and with many spores irregularly embedded through most of its area, indicating a great increase in thickness by irregular proliferation."

" Edible and of the best quality." (McIlvaine).

" The great variability of this plant has led to many names and much confusion.· The large smooth sub-spherical spores, pliable texture and blackening tips are the surest guides." (Coker.)

Cotton and Wakefield only recognized *C. cristata*, *C. cinerea*, and *C. rugosa*, and say that it is possible that *C. cristata* may be a form of *C. rugosa*. Rea recognizes the following species and varieties :—

Clavaria coralloides (Linn.) Fr. (?).
Clavaria cristata (Holmsk) Fr.
Clavaria cinerea (Bull.) Fr.
Clavaria cinerea var. *gracilis* Rea.
Clavaria rugosa (Bull.) Fr.
Clavaria rugosa var. *fuliginea* (Pers.) Fr.
Clavaria rugosa var. *macrospora* Britz.
Clavaria grossa Pers. Quel. (? = *C. Krombholzii*).
Clavaria crassa Britzl. (? = *C. rugosa*).
Clavaria Krombholzii Fr.
Clavaria grisea (Pers.) Fr.

Coker has collected a great number of spore measurements and other details, and concludes that all the forms listed as synonyms can be included in the species *C. cristata*.

Coker states: " We have been unable to find any differences either in gross character or in microscopic detail, of sufficient importance to enable us to distinguish species within the group." Romell stated that he could see no distinct limit between *C. cristata*, *C. cinerea*, and *C. rugosa*.

The commonest variety in Victoria appears to be the *cinerea* form, which is often found much incrassated and proliferated. I have not seen any large, much branched *cristata* forms, but small specimens up to 1½ inches in height are common for the greater part of the year.

Cleland (4) has described a South Australian plant as *C. sub-rugosa*. It is "white, becoming slightly dingy. Pallid Greyish White or near Cartridge Buff. Spores spherical 5.6-7.5μ."

The spores of the South Australian plant are smaller than those given by Cotton and Wakefield for *C. rugosa*, and discussing Coker's work Cleland says: "We have cristate plants which we assign to *C. cristata* and it seems advisable to apply a definite name to these more simple, non-cristate specimens, whose spores do not agree in size with *C. rugosa* of the English workers."

Coker's spore measurements for the *rugosa-Krombholzii* forms are 7-9.3 x 8-11μ, which is larger than in the South Australian form. But under the heading *cristata-cinerea* forms Coker gives spore measurements 5.5-8 x 6.7-10.5μ, so that it is not impossible to include *C. sub-rugosa* as a synonym of *C. cristata*.

Cooke records *Clavaria cinerea*, Victoria: *C. cristata*, Victoria, Queensland, Tasmania; *C. rugosa*, Queensland; *C. Krombholzii*, Victoria. Cotton and Wakefield regard *C. Krombholzii* as synonymous with *C. Kunzei* which they say has spores minutely apiculate, 3.5-4.5μ in diameter. Coker examined a plant identified as *C. Krombholzii* in Fries' collection. The spores are similar to those of *C. cristata*.

Group 7.

Clavaria Nymaniana P. Henn. Monsunia, 1, 1899, p. 9.

(Plate IV., Fig. 2.)

Plants branched irregularly or dichotomously, usually arising several together with the stems closely adpressed, but slender and distinct, up to 10cm. high, usually 5 cm. Branches closely adpressed one to another, axils rounded. Entire plant Slate Violet when fresh, fading to Wood Brown in age. Base of plant distinctly woolly and of the same colour as the plant.

Flesh rather brittle, concolorous with the surface when moist; if the plant is drying, white and cottony; becoming rather pliable towards the base, which is rather elastic and distinctly tough. (When the plant is deeply rooting or small this character is not so marked.) Taste and odour mild.

Spores not copious, white, with a bluish tinge in mass. Microscopically hyaline, smooth, sub-globose, 3-5.5μ with one guttule Habitat—on ground. Localities: Apollo Bay, Mount Evelyn.

C. amethystina Fr. ex Batt., as interpreted by Coker, shows certain similarities with this plant, viz., colour, tender and pellucid flesh and dichotomous branching. Coker's illustrations (pl. 24 and 25) suggest that his plant has the same habit as ours, but the

points in his description which do not agree are. (*a*) spores with one end pointed, (*b*) colour darker uppermost, tinted with buff at the base. In our plant the colour tends to persist at the base when it has faded from the upper parts, (*c*) base apparently smooth. In the Victorian plant the woolliness and toughness of the base is very marked.

Rea's description of *C. amethystina* gives the trunk as concolorous or whitish and the flesh tinged violet, becoming whitish, spores white, elliptical, obtuse at both ends 6-7 x 3-4μ. Cotton and Wakefield say that the smell is strong and the taste tallowy, stem scarcely distinct. Branching irregular, axils not flattened, branches often attenuated. Spores smooth, hyaline, globose, with a minute basal apiculus 5-7μ diameter, turning rapidly to yellowish on drying.

The spores of *C. amethystina* described above are much larger than in the Victorian plant, and in addition the colour and habit are not the same.

C. Nymaniana is closely related to the Victorian plant, and Henning's description fits the Victorian plant fairly well. The only difference lies in the fact that the stem of the true *C. Nymaniana* is smooth, but Henning also states that it is flexible. It has not been possible to obtain a type specimen of *C. Nymaniana*, but in view of the fact that its description agrees closely with that of our plant it is advisable to regard the two as belonging to the same species.

Group 8.

Clavaria subtilis: Fr. ex. Pers. Pers. Comm. T.4, fig. 2.

(Plate III., Fig. 2, Text Fig. 1*b*.)

Plants white, cream in age, slender, 2-4 cm. high growing separately or in tufts, usually with a distinct slender cylindrical stem equal to $\frac{1}{3}$ or $\frac{1}{2}$ the plant in height, from the top of which the few branches arise or branching at the base giving the appearance of two fascicled individuals: the branches are often bent so as to resemble prongs. Stem and branches smooth, glabrous, equal, axils patent. Tips often long, gently tapering to a blunt point. Flesh white, delicate, but rather tough. Internal structure of interwoven hyphae 4.5-8μ thick. Taste and odour none. Hymenium 30μ thick. Basidia with two or four sterigmata. Spores, white in mass, microscopically hyaline, smooth, oval, or rectangular-elliptical, with an oblique apiculus, once guttulate 3.5-4.3 x 2.2-3.6μ. Habitat—on damp soil in gullies, widespread in Victoria.

Coker describes *C. Kunzei* as a rough spored form, but he considers *C. subtilis* Fr. ex. Pers. to be a synonym. His illustration of *C. Kunzei* (pl. 29, Coker) suggests a different plant from the

one Bresadola gives, and also from the Victorian plants. But Coker has examined a plant labelled *C. subtilis* in the Bresadola Collection at the New York Botanical Garden, and says it is exactly like *C. Kunzei* in form and spores. Bresadola's description of *C. subtilis* is "Gracilis, sub-tenax, ramosa, ex albida pallide straminea, 3-4 cm. alta, basi subglabra. Trunco e ramis subaequalis vix 2 mm. crassis. Rami pauci dichotomi, subfastigati, apice attenuate, sporae ellipsoideae-ovoideae, basi distincte apiculatae, hyalinae, leves 3-5 x 2.5-4μ. Bas. clav. 25-30 x 5-8μ." Bresadola's illustration of the plant and its spores suggest that the plant he called *C. subtilis* is the same as our plant. The only difference lies in the fact that he shows spores with two guttules, while those of our plant have one.

Rea considers *C. subtilis* and *C. Kunzei* as separate species, but in neither case does he mention any spore markings. His description of *C. subtilis* fits our plant, except that the spores are larger in his form.

Coker's illustration of *C. Kunzei* suggests a different plant from the one under consideration, and the National Herbarium (Melbourne) specimen of *C. Kunzei* is quite different from it, as it shows an antlered type of branching and has rough spores, which do not resemble those of any plant of this group collected in Victoria.

It is therefore evident that the two plants *C. subtilis* and *C. Kunzei* are distinct species and may be identified briefly as follows:—*C. Kunzei* white, small, showing antlered type of branching, spores rough: *C. subtilis*, white, small, branches dichotomous, cylindrical, spores smooth.

Clavaria Kunzei Fr. Syst. Myc. 1. 474, 1821.

(Text Fig. 1*c*.)

Cooke (8) records this plant from Queensland and a specimen identified by him is in the National Herbarium, Melbourne. He describes it: "Rather fragile, white, very much branched from a thin base (2-6 cm. high), branches elongated, crowded, repeatedly furcate, fastigiate, even, equal, compressed at the axils. Spores sub-globose 9-12 x 8μ, hyaline. In Woods, Queensland."

There is no doubt that this specimen is correctly identified, as it fits Coker's description, but the spore measurements Cooke gives (sub-globose 9-12 x 8μ hyaline) are incorrect. The specimen has sub-globose, hyaline spores 2.5-3.5 x 3.5-4.5μ, which are very rough for their size. It is in a fragmentary condition and is brown in colour, but it shows the typical antlered branching and some scurfy-velvety areas, particularly at the top of the stem.

As the plant has not been collected in Victoria there has been no opportunity to make a description from a fresh specimen. Coker (7) gives an excellent description of the species.

CLAVARIA CINNAMOMEA n. sp.

(Plate III., Fig. 3.)

Plantae parviae gregariae vel solitariae, rarius simplices, saepius ramosae. Stirpes gracilis teres circa 1 mm. lata, non radicans. Rami pauci dichotome summa ex stirpe nascentes. Ramis patentibus axiles partes inferiores ramarum saepe latae. Rami 1-2.5 mm. lati angustiores, teretes, latiores compressi, sulcus utrimque late apertus. Apices obtusi, raro acuti, in plantis juvenilibus obtuse dentate. Color stirpis "Mikado Brown" ad "Sayal Brown," rami superiores et apices "Cinnamon Buff" ad "Pinkish Buff." Sporae leves albae hyalinae gutta unica in distali spori extremo sita, ellipsoideae, extremo apiculo obliquo 2.8-4.2 x 1.9-2.9μ av. 3.45 x 2.42μ. Basidia quattior sterigmatis. Hab. ad terram in silvis. Loc. Cockatoo.

Plants gregarious or solitary, small 1.5-4 cm. high, rarely simple, most often branched. Stem slender, cylindrical, about 1 mm. broad, occasionally slightly bent, not rooting. Branches few, arising dichotomously from the top of the stem. Branching open, axils and lower parts of the branches often flattened, branches 1-2.5 mm. broad, the narrower ones cylindrical and smooth, the broader ones often flattened, with a broad, open furrow on either side. Tips blunt, very occasionally pointed, in young plants bluntly toothed. Colour of stem Mikado Brown to Sayal Brown, of upper branches and tips Cinnamon Buff to Pinkish Buff. Spores smooth, white in mass, elliptical, microscopically hyaline, with one guttule situated in the distal end of the spore, with a prominent terminal apiculus 2.8-4.2 x 1.9-2.9μ, av. 3.45 x 2.42μ. Basidia with four sterigmata. Habitat: on ground in fern gullies. Locality: Cockatoo.

The plant is easily recognized in the field by its characteristic form which resembles that of *C. crocea*, and by its colour, which is always darker at the base. It is distinguished from *C. umbrinella* Sacc. by its smaller spores and rather fleshy texture. In addition the colour of *C. umbrinella* is uniform.

CLAVARIA UMBRINELLA Sacc. Syll. 6, 695, 1888.

Clavaria umbrina Berk. Outlines of Brit. Fung. Pl. 18, Fig. 3-4, 1860.

Clavaria subumbrinella Imai. Trans. Sapporo Nat. Hist. Soc., xiii, Pt. 4, p. 386, 1934.

(Fig. *h*.)

Plants moderately small and simple, up to 5 cm. high, branching dichotomously three or four times from a slender stem which may be fused with others at ground level. The stem may be equal to as much as half or two-thirds the plant in height. Branches cylindrical, about 1.5 mm. diameter; axils rounded, not flattened. General trend of the branches upright. Tips relatively long, and tapering to a blunt point. Colour, Pinkish Buff to

Cinnamon Buff, but with slightly less pink than these shades. Base slightly tomentose, two-thirds of the plant upwards faintly white pruinose. Flesh whitish, firm, opaque, rather fibrous, smell and taste none. Spores, white in mass, microscopically hyaline, sub-globose, smooth, with a minute apiculus 2.2–3.2μ x 3.3-4.2μ. Habitat—on damp ground under scrub. Locality, Mt. Evelyn. Not previously recorded for Australia.

In general appearance the plant resembles *C. Bizzozeriana*, but may be distinguished by its colour and firm texture.

It is to be noted that in Rea's description of *C. umbrinella* the spores are slightly larger than in the Victorian plant, and also that the branches are distinct to the base. Our plant could be so described, or could be interpreted as a cluster of several plants fused at the base.

Imai (14) describes a species *C. subumbrinella* "solitaria, ter quaterve ramosa, umbrina (tawny olive) circa 5 cm. alta, ramis dichotomis, apicibus subacutis, stipite distincto, parte subterranea leniter albo-tomentosa, basidiis clavatis, sporis in cumulo albis crasso ellipsoideis, levibus circa 5 x 3. Hab. ad terram in silvis.

The fungus somewhat resembles *C. umbrinella* Sacc. and is distinguished by the slightly tomentose stipe and by the method of branching. *C. umbrinella* has no stipe and branches at the basal part of the plant".

The only real points of difference between this species and *C. umbrinella* are, (*a*) the slight tomentosity of the base of the stem which is lacking in *C. umbrinella* (but the Victorian plant which fits the description of *C. umbrinella* shows this character), (*b*) the type of branching. The Victorian plants of *C. umbrinella* are all branched right to the base, but *C. Bizzozeriana*, which is obviously closely related, is found growing singly or fascicled in small groups of two or three, which could be regarded as one plant branching from the base (see plate). In this case there is no suggestion that the single plants and those growing in groups are of different species. Accordingly, as the descriptions of *C. umbrinella* and *C. subumbrinella* differ only in minor characters which are intermediate in the Victorian representative of the species, it is reasonable to regard them as synonymous.

CLAVARIA BIZZOZERIANA Sacc. Syll. 6, 693, 1888.

(Plate III., Text Fig. 1*j*.)

Clavaria tenuissima Sacc. Michelia 1, 436, 478 (not *C. tenuissima* Lev. Ann. Sci. Nat., 3rd ser., 5, 156, 1847).

Clavaria conchyliata Allen. Trans. Brit. Myc. Soc., 3, 92, 1908.

Plants branched, small and delicate 1-3.5 cm. high, solitary or a few together, growing on bare ground or amongst moss.

Stem slender, usually half the plant in height, often white pruinose below. Branching dichotomous and open, the branches cylindrical, comparatively long and slender and curved inwards slightly so that they resemble prongs. Axils rounded, not flattened, tips sub-acute, tapering gently to a blunt point. Young plants simple and club-like, about 1 cm. high and with a few small teeth at the apex. When young the entire plant is Slate Violet or Ramier Blue, in age the base becomes Avellaneous and the branches Greyish Lavender. Flesh solid, concolorous, fading with the surface, pliable, and except at the ultimate branches, which are very brittle and fragile, not snapping with a clean break when bent. Flesh of stem becoming fibrous in age. Spores smooth, hyaline, globose, 2.5-3.5μ diameter, minutely apiculate, white in mass, microscopically hyaline.

Our plants fit the description of *C. Bizzozeriana* as given by Cotton and Wakefield. But Coker considers *C. Bizzozeriana* a synonym of *C. pulchella* Boud. Boudier describes *C. pulchella* as having flattened branches and denticulate tips. The spores of his plant are 4–5μ long, oval. Also the stem and lower parts of the branches are white, only the upper parts of the plant being violet. Boudier's illustrations are reproduced in plate 3, fig. 4, and from these it can be seen that our plants do not resemble *C. pulchella* in form, having rounded branches, entire tips and globose spores, and an almost uniform violet colour. Coker has not seen *C. Bizzozeriana* in the living state but regards *C. exigua* Pk. as the same. The description he gives of *C. pulchella* (= *C. Bizzozeriana*) is adapted from Peck's account of *C. exigua*. From this description it may be seen that *C. exigua* and *C. pulchella* have a similar habit and colour distribution, and the spores are alike, so it is possible that they are synonymous. *C. Bizzozeriana* differs from them both in not having a white base, and in spore size. These differences are sufficient to justify keeping *C. Bizzozeriana* as a separate species.

In 1878 Saccardo first named the plant known as *C. Bizzozeriana*, *C. tenuissima*, but, as Leveille had, in 1847, already given another plant this name, Saccardo changed the name to *C. Bizzozeriana* in 1888. *C. conchyliata* Allen is regarded as synonymous with *C. Bizzozeriana* by Rea, and Cotton and Wakefield, and the descriptions agree well.

It is interesting to note that *C. arborescens* which Berkeley described from New Zealand (Hooker, Fl. N.Z., 11, p. 186, London, 1855) may be the same as *C. Bizzozeriana*.

The description is "sparsa, amethystina, gracilis, stipite tenui elongato, simplici, ramis furcatis fastigiatis, ultimis brevissimis, acutis". In the absence of details of spore characters it is impossible to be certain of the identity of the plant.

Clavaria crocea Fr. ex. Pers.

Pers. Comm. p. 57 (189), 1798.

(Plate IV., Fig. 3, Text Fig. 1*g*.)

Plants small, growing in groups, but not fascicled, 1–5 cm. high, branching from a slender stem, which is long or sometimes quite short, occasionally slightly tomentose, equal to about half the plant in height, in age a darker colour than the branches. Branches arising dichotomously from the top of the stem, three or four times furcate; axils rounded, often flattened, in which case the branches have an antlered appearance and show several broad, shallow longitudinal furrows. Branches often smooth and sub-cylindrical: tips blunt. Colour, Orange, Capucine Yellow, Orange Buff, the base of the plant darker than the tips. In age fading to Light Orange Yellow with somewhat yellower tips.

Flesh concolorous, soft and brittle, more flexible when old. Smell none, taste mild, occasionally bitter. Basidia with four sterigmata, spores distinctly rough, white in mass, microscopically hyaline, sub-globose once guttulate. In sheltered places, or among grass and moss in more open situations.

Cooke records this species for Victoria but gives an inaccurate spore measurement ("spores ellipsoid, 6–7 x 2–3μ"). Cleland has recognized it in South Australia and gives an illustration of typical plants, which are much smaller than the Victorian ones. Coker says *C. crocea* is one of the rarest Clavarias and is unsurpassed for delicacy and beauty. Although he says the plant has been collected only a few times since Persoon's day, it is not uncommon in Victoria and reaches a large size.

Cotton and Wakefield exclude *C. crocea* as being indeterminable The specimens on which Berkeley based the English record are at Kew but show no spores.

Clavaria pyxidata Fr. ex. Pers. var. *asperospora* n. var.

Pers. Comm. p. 47, (179), 1797.

Fr. Hym. Eur., 669, 1871.

(Plate IV., Figs. 1, 4, 5, Text Fig. 1*k*.)

Plants up to 10 cm. high, often extremely small, springing in clumps or singly from decaying wood. Main stem slender, sometimes somewhat pubescent, sometimes with brown hispid fibres at the base. "Stems round, often channelled, becoming thicker upwards dividing simultaneously like an umbel into several branches, which spread out rather strongly and then turn up again, primary branches expanding suddenly at their tips into little cups, from the margins of which spring the branchlets of

the third degree. These may again end in cups with similar branches which finally terminate in smaller cups with little teeth on the rims". (Coker, p. 94). Colour, Wood Brown to Avellaneous, base Cinnamon Brown. Flesh quite pliable and not at all brittle except at the tips, tough, especially at the base. Very peppery to the taste. Spores pure white in mass, definitely roughened, sub-globose 3.2–4 x 4–4.8μ. Basidia 4-spored, 3.5–4.6μ thick, inconspicuous, hymenium about 30μ thick with many projecting cystidia of two kinds, either fusiform, pointed, hyaline, and with scanty cell contents, or cylindrical with rounded tips, somewhat resembling the gloeocystidia of *Physalacria*. Hyphae just beneath the hymenium, fine, 3.5μ thick, varying to 11μ in the centre, clamp connections present. Always found growing on decaying wood (in Australia chiefly on Eucalypts, rarely on Acacias, etc.).

This species is very widely distributed in Victoria and in most temperate parts of the world. It is easily recognized in the field by the cup-shaped expansions at the ends of the branches, the brownish colour, and the peppery taste.

The form of *C. pyxidata* which occurs here shows certain differences from the type viz.: brown hispid fibres are often absent from the base, brownish colour even when young, and, chiefly, in having spores which are distinctly rough. The European and American plants are "rather light clear yellow" when fresh, have hispid fibres at the base and, in addition, smooth spores. Accordingly, although the two forms have exactly the same type of branching and both possess cystidia of two kinds, it was decided to describe the Australian plants as a new variety.

Clavaria pyxidata var. *asperospora* n. var.

Forma habitusque similis Clavariae pyxidatae *Fr. ex. Linn. Color "Wood Brown" ad "Avellaneous". Basis "Cinnamon Brown" pubescens saepe sine fibris hispidis, sporae hyalinae, sub globosae, perspicue asperae* 3.2–4 x 4–4.8μ. *Loc. Sherbrooke, Victoria.*

"Branching and habit like *C. pyxidata* Fr. ex. L. Colour Wood Brown to Avellaneous. Base Cinnamon Brown, pubescent, often without hispid fibres. Spores hyaline, sub-globose 3.2–4 x 4–4.8μ distinctly rough. Sherbrooke, Victoria".

I have examined plants from Victoria and Tasmania and find the characters mentioned constant. Cleland does not record the species for South Australia, Cooke records it for New South Wales and Victoria. Cotton and Wakefield do not recognize *C. pyxidata,* regarding it as possibly an abnormal form of *C. stricta.* It seems that they have not examined it in the fresh state, as it is one of the most easily recognized species. Its

peculiar type of branching is unmistakable; also its spores admit of no confusion with those of *C. stricta* as they are white and sub-globose; *C. stricta* has ochraceous, pip-shaped or elliptical spores 6–9 x 4–5μ.

Group 9.

Clavaria crispula Fr. Syst. Myc., 1, 470, 1832.

(Plate V., Fig. 2, Text Fig. 1*m*.)

Plants branched, up to 5 cm. high, growing in colonies among pure wood debris around or under trunks. Subiculum very extensive, white, ropy or effused, stems arising from this, about 2–3 mm. diameter, rather woolly at the base, and with several rhizomorphs attached. Stems branching a short distance above the base into two or three main branches, which divide irregularly or dichotomously once or twice to form a large number of fine ultimate branchlets, which are often less than 0.5 mm. broad, (usually 0.5–1 mm.). Branches rounded, rather flexuous, but generally tending in an upright direction. Tips subulate and divaricating.

Colour, creamy when fresh, Ochraceous when old, the tips usually lighter than the body of the plant; entire plant on drying Isabella Color. Flesh concolorous, creamy, not changing colour on bruising, soft and dry, not breaking when bent upon itself, pliable and resilient. On drying the branches become hair-like and very fragile.

Spores ochraceous, copious, slightly colored when examined microscopically, elliptical to pip-shaped, with an oblique terminal apiculus, 6–6.9 x 3.2–4.1μ distinctly roughened, almost spiny. Hymenium smooth, basidia with four sterigmata. Locality, Cockatoo. May. Not previously recorded for Victoria. Recorded by Cooke (8) for Western Australia.

The soft toughish texture of this plant distinguishes it from any other *Clavaria* occurring in Victoria. Rea (16) gives Massee's description of *C. crispula*. This fits our plant, except that the spores are said to be 5 x 3μ. These are slightly smaller than those of the Victorian plant, but Massee makes no reference to their roughness. Cooke also gives Massee's description. Coker (7) lists *C. crispula* as a doubtful synonym of *C. decurrens* Fr. ex. Pers., but comparing our plant with Coker's description of *C. decurrens* it is evident that they are not the same. The flesh of *C. decurrens* stains pink when bruised, the branches are angular and flattened, and the spores are smaller than in our form, which has rounded branches, the flesh not staining pink when bruised. Another point is that in our plant the hymenium is single. In *C. decurrens* it proliferates. The Victorian plant

is distinct from any other I have collected, and, as it fits the description of *C. crispula* as understood by Massee and Rea, I would prefer to regard it as distinct from *C. decurrens*, as described by Coker and to place it in the species *C. crispula*.

CLAVARIA GRACILIS Fr. ex. Pers. Comm. p. 50 (182) 1797.
(Plate V., Figs. 1 and 3, Text Fig. 1*l*.)

Clavaria alutacea Lasch. in Rabenhorst Klotzschii Herbarium Vivum, Mycologicum Cent. 16, No. 1519, 1851.

Clavaria fragrans E. & E., N. Am. Fungi, 2nd ser., No. 2033, 1888.

Clavaria fragrantissima Atk., Ann. Myc., 6, 57, 1908.

Clavaria flavuloides Burt., Ann. Mo. Bot. Gard., 9, 28, pl 5, fig. 34, 1922.

Plants 3–9 cm. high, 1–6 cm. broad, gregarious, often crowded in extensive clumps, sometimes growing in rings. Plants slender and delicate, varying to large and rather firm, mycelium forming a distinct layer beneath the surface of the mass of pine needles, and binding the needles and other debris together. Trunks 3–7 mm. diameter, 1–3 cm. in length, arising directly from the mycelium, with a few large rhizomorphic strands attached; branching dichotomously six or seven times in an upright fashion, the ultimate branches ending in short, acute irregular processes which often divaricate. Branches usually flattened at the axils, which tend to be lunate in the lower parts of the plant, but somewhat compressed in the upper parts. Colour, body of the plant Warm Buff or Light Ochraceous Buff or paler; tips, Ochraceous Salmon or Whitish. Flesh paler than the surface, not changing colour when cut or bruised, soft and delicate, but not brittle. Odour distinct, faintly medicinal, disappears on drying, taste faint, but similar. Spores pale ochraceous, broadly elliptical with an obliquely terminal mucro, slightly rough, varying to almost smooth, 3.3–4.9 x 4.8–6.2μ. Basidia 4.5–6μ thick with four sterigmata, hymenium 40–50μ thick. Threads of flesh and subiculum between 3 and 9μ wide, showing clamp connections. Habitat, among fallen needles beneath *Pinus insignis*. Locality, Durdidwarrah, Brisbane Ranges. June. Not previously recorded for Victoria. Recorded by Cleland for South Australia. This plant is readily recognized in the field by its place of growth, slightly fragrant odour and by its colour.

Coker's illustrations and descriptions are in very close agreement with the plant as it occurs here. He states that Persoon's original description fits the American plants perfectly.

CLAVARIA STRICTA Fr. ex. Pers. Hym. Eur. 673.
(Plate V., Fig. 4. Text Fig. 1*n*.)

Lachnocladium Atkinsonii Bres. Journ. Myc. 8, 119, 1902.

Clavaria leucotephra B. & C. Grevillea 2, 7, 1873.

Clavaria condensata Fr. Epicr., p. 575, 1838. (Sense of Bresadola and Romell.)

Clavaria syringarum Pers. Myc. Europ. 1, 164, 1822.

Clavaria Kewensis Mass. Journ. Bot. (Britten's) 34, 153, 1896.

Lachnocladium odoratum Atk. Ann. Myc., 6, 58, 1908.

Clavaria Lorithamnus Berk. Aust. Fungi, No. 46, Journ. Linn. Soc. London, 1872.

Plants branched, up to 7 cm. high and 5 cm. broad, growing on decaying wood, or on soil with a large admixture of wood debris; stem arising from a more or less distinct hyphal layer and usually with several white rhizomorphic strands attached to it, slender, pubescent, dividing rather quickly and irregularly into many smaller branches which, after branching once more, divide to form the pointed apices. Axils very narrow, not flattened. Branches always very erect, top of the plant usually pointed. Colour of main part of the plant between Honey Yellow and Isabella colour, or Ochraceous Buff or Light Ochraceous Buff, tips creamy. Taste and smell like radish, and rather strong. Flesh soft and translucent but tending to be tough, when old very brittle and watery. On drying, the plant becomes hard and the surface appears woolly and the colour becomes uniformly Chamois or Honey colour. Spores ochraceous, 3.5–4.5 x 6.3–9μ, elliptic with a large obliquely terminal mucro, distinctly rough, almost tuberculate in some collections. Basidia with four sterigmata 7–9.2μ thick about 40μ long. Localities: Healesville and Bayendeen. Not previously recorded for Victoria. In the field this species is chiefly distinguished by its compact appearance, erect branches, and strong smell and taste of radish.

The plant which I am calling *C. stricta* shows certain points of difference from the true *C. stricta.* It has no sterile areas of different appearance from the rest of the plant, showing a roughish, plush-like surface under a lens. These are said to be quite extensive in *C. stricta* as it occurs in other countries. The spores in the Victorian specimens are much rougher and slightly smaller than for well authenticated specimens of *C. stricta.* Of *C. stricta* it is said that many spores show the contents collapsed away on one side, near the mucro, giving the appearance of a very long and abrupt mucro. I have not observed this.

Cooke recorded *C. stricta* for New South Wales and Queensland and his description fits our plant very well.

Clavaria lorithamnus Berk. is described as "pallid umber, branches straight, apices shortly bifid and rather acute, 4 cm. high, spores hyaline. On the ground, Victoria. This is said to have exactly the form of *C. stricta,* but to have no rhizomorphs at the base."

Some of the specimens of *C. stricta* which have been sent to me have been reported as growing on the ground, but further

enquiries revealed that they were attached to buried wood or to be growing in soil rich in decaying wood, and in some cases rhizomorphs were absent.

I have not been able to obtain a specimen of *C. lorithamnus*, but in view of the occurrence of *C. stricta* without rhizomorphic strands there is no doubt that *C. lorithamnus* is merely an abnormal form of it.

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Explanation of Plates.

All illustrations are natural size.

Plate I.

Fig. 1.—*Clavaria muscoides.* Simple plants.
Fig. 2.—*C. muscoides.* Large complex plant.
Fig. 3.—*C. cristata.* Small, sparingly branched, white form.
Fig. 4.—*C. cristata.* Incrassated *cinerea* form.
Fig. 5.—*C. cristata.* *Rugosa* form.

Plate II.

Fig. 1.—*Clavaria cristata.* Most of these plants show the wrinkling of the surface typical of the *cinerea* form, but there is also a tendency towards the production of cristate branches in the upper parts of the plants.

Plate III.

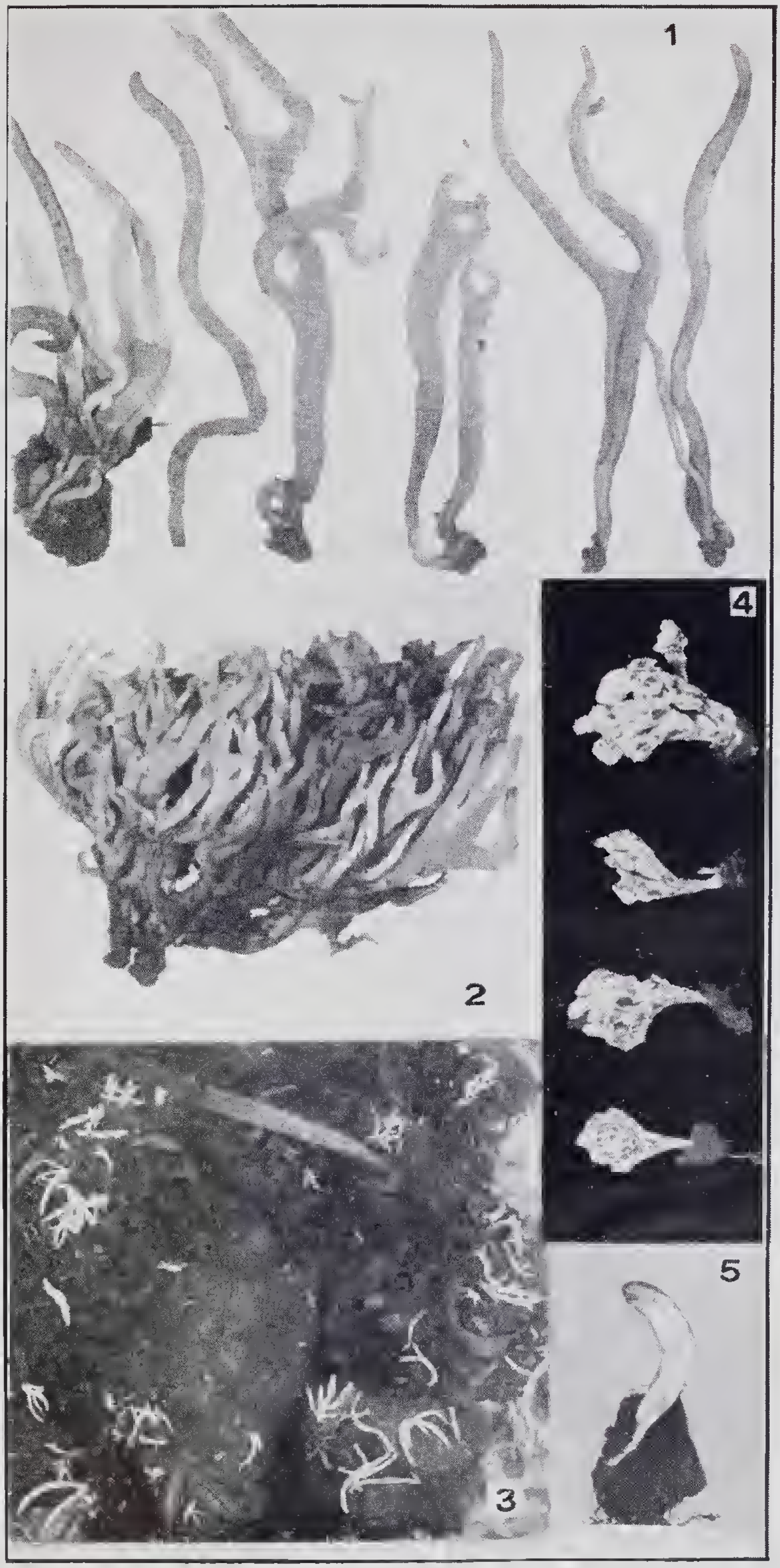
Fig. 1.—*Clavaria Bizzozeriana.* All types of plants between simple clubs and relatively large and complicated forms are shown. (The tips of some plants are shrunken through drying.)
Fig. 2.—*C. subtilis.*
Fig. 3.—*C. cinnamonea* (type).
Fig. 4. Boudier's illustrations of *C. pulchella*. iia shows entire plant with white base, iid the denticulate tips and iie the elongated spores.

Plate IV.

Fig. 1. *Clavaria pyxidata* var. *asporosposa*, showing branches arising from cup-like expansions. Medium sized plants.
Fig. 2.—*C. Nymaniana.*
Fig. 3.—*C. crocea.*
Fig. 4.—Minute plants of *C. pyxidata.*
Fig. 5.—Large single plant of *C. pyxidata* var. *asperospora*. Notice that the branching is typical in the upper parts of the plant, but thickening of the branches at the base has obscured the cup like expansions.

Plate V.

Fig. 1.—*Clavaria gracilis.* Two clumps composed of small plants.
Fig. 2.—*C. crispula.*
Fig. 3.—Large plant of *C. gracilis.*
Fig. 4.—*C. stricta.* Single plant, base missing.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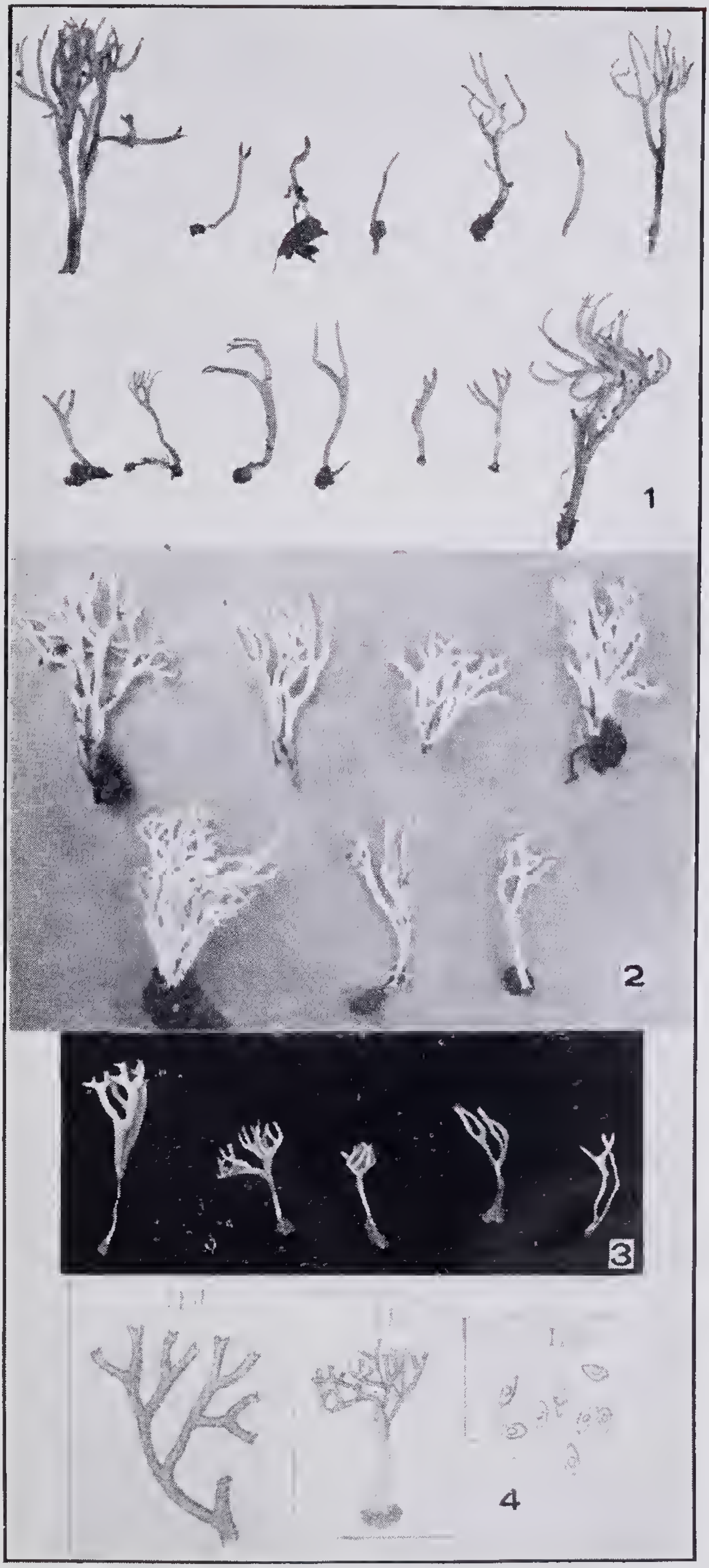
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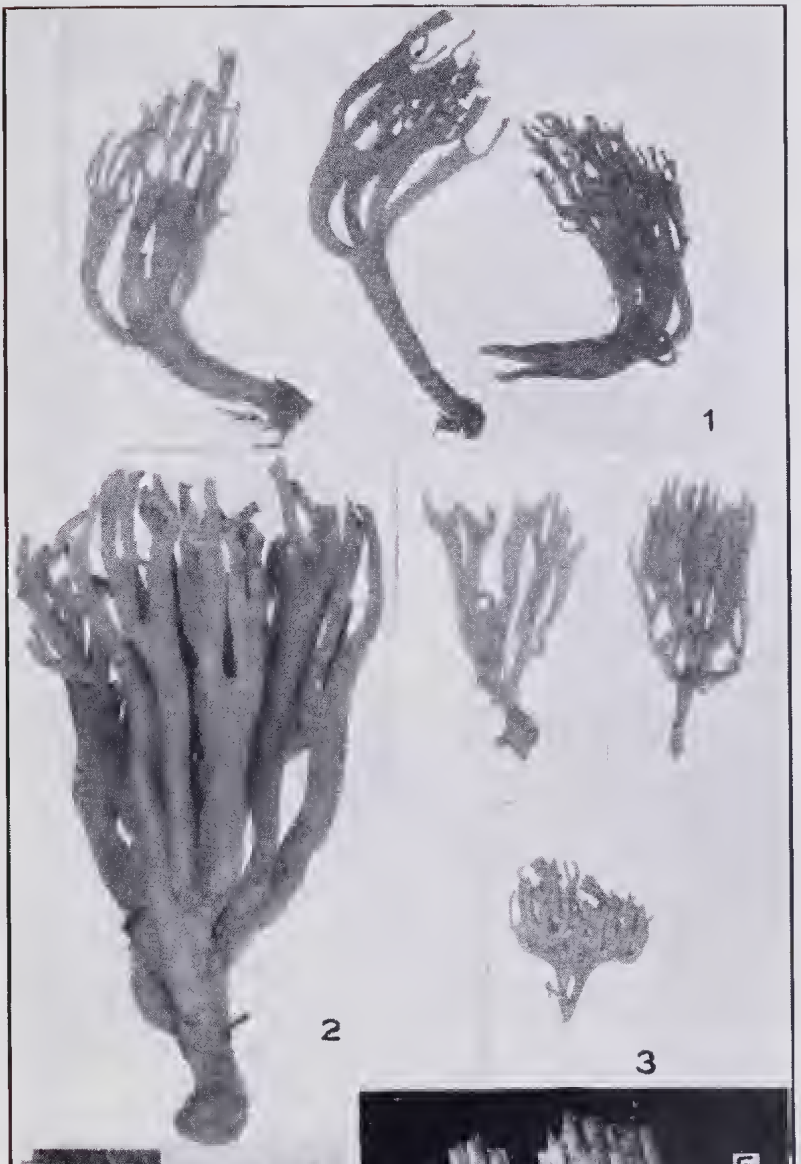
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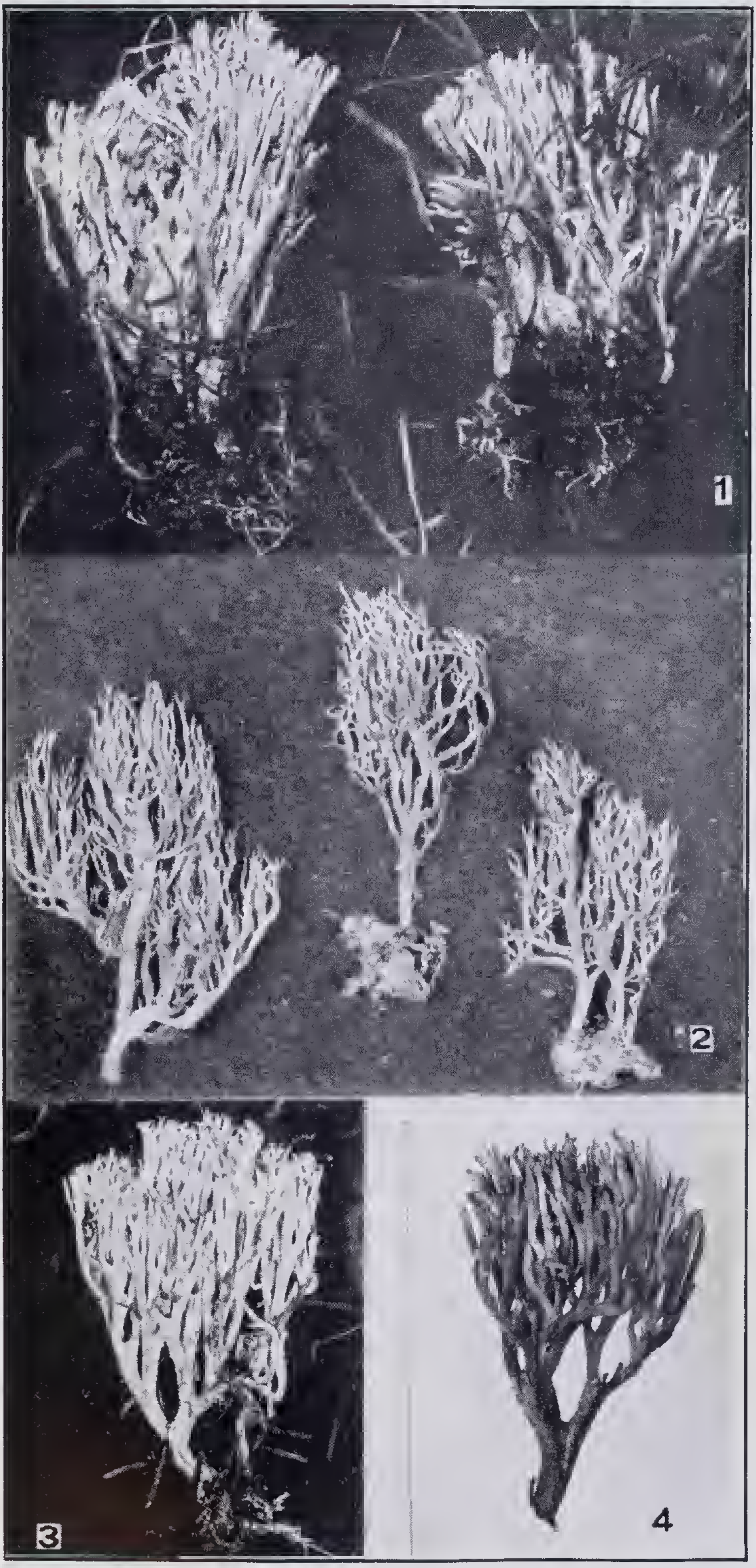
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[Proc. Roy. Soc. Victoria, 51 (N.S.), Pt. I., 1938.]

Art. II.—*Granite and Granodiorite at Powelltown, Victoria, and their Relationships.*

By GEORGE BAKER, M.Sc., ALAN GORDON, B.Sc., and D. D. ROWE.

[Read 12th May, 1938; issued separately, 23rd January, 1939.]

Introduction.
Nature and Distribution of the Rocks in the Area:—
 Altered Sediments.
 Granodiorite.
 Granite.
 Xenoliths.
 Dykes and Veins.
Relationship of Granodiorite and Granite.
Petrology.
Summary and Conclusions.
References.

Introduction.

The main purpose of this paper is to record the relationship between granodiorite and granite at Powelltown in the parish of Beenak, County of Evelyn, about 45 miles due east of Melbourne (fig. 1).

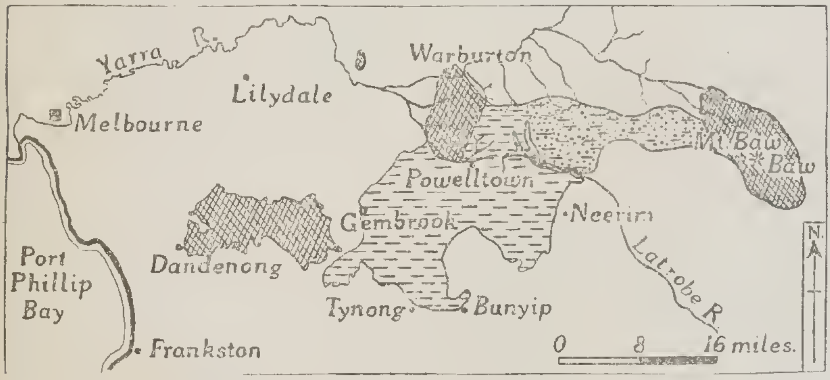

Fig. 1. Locality Map showing the Relationship of Outcrops of Granodiorite (cross hatching) to Granite (broken horizontal lines). Stippled area represents unclassified granite rocks.

The close proximity of granodiorite and granite in the Powelltown district was discovered by Mr. A. Gordon in 1936; field work which showed that the granite intruded the granodiorite was carried out by the authors in September, 1937, and the petrological relationships and the manuscript have been prepared by the senior author. The map accompanying the paper is based on contour plans prepared by the Forests Commission and by the Defence Department of Victoria.

Rock exposures in the Powelltown area are limited by conditions which have been very favorable for the accumulation of rock debris and soil. The examination of the granitic rocks was confined to a few road cuttings, a quarry, timber track clearings and one or two cleared hills on which soil erosion has occurred. Stream courses supply sparse geological exposures since sands, gravels and soils are deep, and plant growth very luxuriant, masking all critical geological boundaries. The information obtained from the area, however, is sufficient to indicate that of the two plutonic intrusions present, viz., granodiorite and granite, the granite is the younger.

The topography of the area is essentially a youthful one, characterized by fast flowing mountain torrents which drain into the mature valleys of the Latrobe River and the Little Yarra River. These are the two main streams in the area, the Latrobe flowing in an easterly direction, and the Little Yarra in a diametrically opposed direction. Whereas the tributary valleys of these two rivers are very youthful in aspect, with downward cutting far in excess of lateral widening, the mature valleys of the Latrobe and Little Yarra have built up flood plains nearly a quarter of a mile wide. The low divide which separates the Latrobe from the Little Yarra River in the eastern portion of the area, is locally known as The Bump; it is no more than 50 to 75 feet above the two rivers, and is barely a quarter of a mile wide. Minor streams in the area trend in two directions mutually at right angles, which suggests that two major systems of rectangular joints in the two intrusions are similar in strike and control the stream directions. The trend of the Little Yarra River has been mainly determined by the boundary between the granodiorite and the granite.

Nature and Distribution of the Rocks in the Area.

The rocks of the Powelltown District consist of granodiorite and granite with numerous xenoliths and three small areas of Silurian sediments. The granodiorite is a large stock occupying the north-western portion of an extensive area mapped as granitic rocks on the geological map of Victoria. The bulk of this mapped portion is a batholith of granite, extending from Powelltown in the north, to Gembrook in the south-west, Neerim in the south-east, and Tynong, Garfield, and Bunyip in the south as shown on fig. 1. The rock from Mt. Baw Baw has been described and mapped as granodiorite (2), but its extent and relationship to the granite have not been indicated.

Altered Sediments.

The small isolated areas of sediments are probably Silurian because rocks of this age occur a mile or so west of Three Bridges and outcrop as normal mudstones from here to Yarra

Junction. The main localities are (i) the head of Blackwood Gully, north of Reid's timber mill site, (ii) on the north side of the road south-east of Mt. Myrtalia, (iii) on the timber track between Powelltown and Gilderoy, and (iv) near the junction of Black Sands Creek and the Little Yarra River, about half a mile beyond the western limits of the map.

In addition to these occurrences, occasional residual boulders and pebbles occur on Big Bertha firebreak, in Seeley's Creek and just north of Lloyd's timber mill site. The outcrops in the north-central portion of the area are probably either roof pendants in the granite or rafts of included sediments; they occur some 80 yards or so from the boundary between the granite and granodiorite, and therefore do not form a continuous sheet separating the two intrusions. The outcrop between Powelltown and Gilderoy is a small remnant surrounded by hillwash. Near the junction of Black Sands Creek and the Little Yarra River, the Silurian cannot be observed in contact with the granodiorite because of soil and vegetation.

The Silurian rocks consist of hornfels, quartzite and slighfly metamorphosed sandstones which occur on the surface as fragments, no definite bedding being visible. The width of the metamorphic aureole is indeterminate; it could not have been very great, since narrow remnants in the granite near the granodiorite boundary consist of slightly altered sediments as well as metamorphosed types.

GRANODIORITE.

The granodiorite occurs in the north-western part of the area; it is continuous from Powelltown to Warburton in a northerly direction, and the area of the outcrop is about 45 square miles. The rock is fine-grained, and as at Warburton, contains occasional quartz nodules (4, p. 174).

The best exposures occur in cuttings along the Black Sands Creek road, and in the northern part of the area where recent road construction has exposed fresh rock. Reasonably fresh outcrops occur near the granite boundary half a mile or so north of Reid's, along the timber track clearings.

GRANITE.

The granite covers a larger area than the granodiorite, occupying the southern, eastern and north-eastern portions of the area. Beyond the area, the geological map of Victoria shows it to be continuous with the granite at Gembrook. It has a porphyritic character and is much coarser-grained and lighter in colour than the granodiorite.

A road cutting between Powelltown and Nayook West has exposed fresh granite near Old 13 timber mill site, and a large face has been exposed in a ballast quarry at The Bump, near

Nayook West. At this quarry, portions of the granite have undergone pneumatolytic alteration, and portions have been altered to a clayey mass consisting of halloysite, a mineral of the kaolin group, which also occurs as veins following the joint planes in the granite.

XENOLITHS.

Xenoliths are more common in the granodiorite than in the granite, and never exceed 12 inches across, being often as small as half an inch in diameter. They are usually fine-grained, but may occasionally be porphyritic. Some contain numerous biotite clots, and some show well marked schistose structures, especially those contained in the granodiorite in the western portions of the area. Schistose examples are infrequent in the granite.

Both melanocratic and leucocratic types are represented; by granitisation, the melanocratic examples become lighter in colour, and with mechanical disintegration, become strewn about in the host rocks, their presence being detected by indistinct spots or by clots of ferromagnesian minerals in the plutonic rocks. The leucocratic xenoliths comprise rare examples of quartzite which sometimes exhibit junctions with altered argillaceous types.

In rare examples, stringing out and partial granitisation of some of the xenolithic material has resulted in the production of imperfect schlieren-like structures in the granite, but such have not been observed in the granodiorite. Occasional pools of granitic material have been introduced into some of the inclusions, and in others, the dark coloured ferromagnesian minerals are more concentrated at junctions with the host rock.

The xenoliths invariably possess rounded outlines, produced by magmatic corrosion or by the breaking off of curved portions due to expansion on immersion in the hot magma. Contacts with the host rocks are often embayed, and at times the margins of the xenoliths are pronouncedly inshot with granitic material.

DYKES AND VEINS.

Veins and occasional vughs of pegmatitic quartz and felspar with tourmaline and bladed biotite, cut the granodiorite near the boundary with the granite along Seeley's Creek, on Big Bertha firebreak and north of Reid's. Partially kaolinised pegmatite also cuts the granite in the quarry at Nayook West.

Fragments of fine-grained aplite are common on the surface throughout the area, and in a few examples veins of aplite 1 inch wide and dykes up to 5 feet in width, cut through granodiorite and granite, but no examples could be traced laterally for more than a distance of 20 feet.

Quartz veins cut through Silurian quartzite north of Reid's where there is also a two inch vein of granite cutting the granodiorite. In this vein of granite, biotite is not as abundant as in the more normal portions of the main mass of the granite, and its contact with the granodiorite is relatively sharp.

Relationship of Granodiorite and Granite.

Although contacts between the granodiorite and granite at Powelltown are masked by rock debris and dense vegetation, several factors exist which indicate the relationship of the two intrusions. As far as their age is concerned, all that can be adduced from this area is that they are post-Silurian and pre-Recent. Evidence from other parts of Victoria indicates that the granodiorites and granites are generally Upper Devonian or early Carboniferous, and by analogy the Powelltown occurrences are considered to be of similar age.

Observations which serve to indicate that the granite is younger than the granodiorite are as follows:—

(i) In the hills south and east of the junction with the granodiorite, the granite is usually porphyritic, with the groundmass medium, even-grained, but in parts along the line of contact, it is not so noticeably porphyritic and is rather finer-grained, suggesting that the granite was chilled against already solidified granodiorite.

(ii) Xenoliths of sedimentary origin are numerous in the granodiorite right up to the granite contact, but in the nearby granite only one xenolith of sedimentary parentage has been observed, although sedimentary xenoliths are abundant in the granite further away from the contact. It is assumed from this that the granodiorite intruded the Silurian first, obtaining numerous xenoliths from stoped off blocks of sediment; the granite followed at a later date, and transected both the Silurian and the granodiorite, obtaining more xenoliths from the Silurian rocks than from fragments already contained in those portions of the granodiorite which became engulfed in the granite.

(iii) Near the contact on Big Bertha and north of Reid's, the granite contains included blocks of granodiorite with sedimentary xenoliths in them.

(iv) The abundance of aplite, quartz and pegmatite veins and dykes in the granodiorite near its contact with the granite, especially on hill slopes near Seeley's Creek and north of Reid's, is suggestive that the granite is the younger of the two intrusions.

(v) Near the contact north of Reid's, a vein of granite 2 inches wide cuts through a large boulder of granodiorite.

There are no metamorphic changes visible along the line of contact, but microscopic investigations show that samples of granodiorite from near the contact possess more abundant quartz, occasional pools of which are in optical continuity; orthoclase crystals are larger and more numerous; occasional micrographic intergrowths occur, and the lime felspars frequently show sericitisation. These factors indicate slight thermal metamorphism of the granodiorite, with the introduction of small amounts of granitic constituents.

Petrology.

Altered Sediments.

The less altered Silurian rocks consist of fine-grained micaceous sandstones in which quartz grains are set in a ferruginous or argillaceous cement containing muscovite, rounded zircon, biotite, iron ores and rare tourmaline. In examples from north of Reid's, quartz is set in an aggregate of sericite fibres and chlorite.

The quartzites are fine-grained rocks which have developed from the recrystallization of relatively pure sandstones; any impurities present have been metamorphosed to form rutile, biotite, muscovite, apatite, zoisite and iron ores in small amounts, or have remained as unaltered, rounded grains of zircon. Some of the original sediments from which the quartzites developed were not quite as pure as others, since they possess greater quantities of muscovite; pneumatolytic tourmaline has been introduced into some of the quartzites. One variety of the quartzites was apparently developed from the alteration of a calcareous sandstone for it contains abundant grains of diopside interstitial to the quartz grains. The texture of this diopside quartzite is granoblastic, sphene occurs in subordinate amount, and the only other minerals present are rounded zircon and occasional ilmenite.

In some types of hornfels, the laminations present are suggestive of preserved bedding planes, but the majority are dense and even-grained. Spotted hornfels from the firebreak on Big Bertha is composed of cordierite, biotite, muscovite, some quartz, rounded zircons and iron ores, and the spotted appearance is due to the cordierite which is often crowded with numerous small plates of biotite. Cordierite-biotite hornfels from near the junction of Black Sands Creek and the Little Yarra River, is comparable with types described from the Bulla contact zone (7),

containing cordierite, biotite, iron ores, rounded zircons, apatite, muscovite and tourmaline. Quartz-biotite-cordierite hornfels from the right bank of Seeley's Creek, but not in situ, is coarser-grained than the cordierite-biotite hornfels and has a more vitreous lustre; some of the cordierite crystals in it have been corroded by the quartz.

In all these metamorphosed sediments, even when they occur as xenoliths, the original rounded detrital grains of zircon persist unchanged by metamorphism.

The Granodiorite.

The granodiorite is a fine and even-grained rock composed of quartz, orthoclase which is sometimes microperthitic and poikilitic, oligoclase-andesine, abundant biotite with numerous inclusions and pleochroic haloes, chlorite with sphene and ilmenite along the cleavage planes, apatite and zircon, and occasional small veins of tourmaline which sometimes replace biotite. Symplektitic intergrowths occasionally develop at orthoclase-plagioclase contacts. Portions of the granodiorite near the granite boundary show slight changes due to metamorphism. The introduction of numerous small patches of quartz has developed a sieve structure in the biotite in parts of the rock.

Micrometric analyses of the granodiorite at Powelltown and Warburton (4, p. 173) show the main minerals to be present in the following proportions:—

Table 1.

	I.	II.
Quartz	31·2	28·1
Orthoclase	16·3	12·4
Plagioclase	31·6	34·5
Biotite	18·6	24·0
Accessories	2·3	1·0

I.—Granodiorite, Powelltown.
II.—Granodiorite, Warburton.

The Powelltown analysis, representing the southern, and the Warburton analysis representing the northern portion of the intrusion are closely similar. Table 1 shows that quartz, orthoclase and accessory minerals are slightly greater, whilst plagioclase and biotite are smaller in amount at Powelltown. This is perhaps due to the proximity of granite and the assimilation of sedimentary material at Powelltown, whilst at Warburton, the granodiorite has no known neighbouring intrusion of granite from which additional quartz and orthoclase could have been introduced, and has assimilated dacite as well as sediments.

The following table (Table 2) indicates that the heavy mineral assemblage and index number of the granodiorites at the widely separated localities of Powelltown (I.) and Warburton (II.) are again similar:—

TABLE 2.

——	I.	II.
Apatite (colourless)	C	C
„ with pleochroic cores	V	..
„ (corroded)	V	..
Biotite	A	A
Chlorite	o	A
Garnet	V	V
Hornblende	..	r
Hypersthene	..	o
Ilmenite	V	o
Pyrite	o	r
Sphene	V	..
Tourmaline	V	..
Zircon (colourless)	o	o
„ (pale yellow)	V	V
„ (inclusions in)	o	r
„ (zoned)	V	V
„ (corroded)	V	V
„ (water clear)	V	V
„ ("torpedo")	V	V
„ (pyramidal)	V	V
Zoisite	V	o
Specific Gravity	2·72	2·72
Index Number	16·9	19·9

A = very abundant; C = common; o = occasional; r = rare; V = very rare.

At Powelltown, the tourmaline has been introduced from the later granite intrusion, whilst the hornblende at Warburton has been produced from the assimilation of dacite, and the hypersthene is probably a residual product of the dacite. The higher index number in the Warburton area is attributed to the presence of slightly more chlorite, biotite and ilmenite, generated from the breaking down of the hypersthene in dacite xenoliths.

THE GRANITE.

The granite is a light coloured, medium-grained to porphyritic potash granite containing orthoclase, quartz, acid oligoclase, biotite, secondary muscovite and accessory minerals. Orthoclase is often microperthitic; biotite does not contain nearly as many inclusions and haloes as do crystals of biotite in the granodiorite, and it sometimes shows dactylitic intergrowth with quartz. Chloritisation of the biotite is not uncommon, and the chlorite contains epidote as well as the other by-products of the alteration, sphene and ilmenite. Symplektitic pustules occur at some of the orthoclase-plagioclase contacts, and such intergrowths are more common in the granite than in the granodiorite of this area.

Veins of orthoclase which are interstitial between quartz crystals, show that the crystallization of the orthoclase overlapped that of the quartz; a similar occurrence in the granodiorite

suggests that this late-crystallization orthoclase may have been derived from partial soaking in of granite magma near the end stages of solidification. In some instances, quartz has embayed biotite plates, and in the bays, numerous small apatite and occasional zircon crystals included in the quartz, were formerly inclusions in the biotite. Occasional clusters of biotite plates associated with numerous apatite crystals are remnants of xenolithic strew, whilst poikilitic quartz and orthoclase also indicate digestion of xenolithic material.

In the quarry at Nayook West, portions of the granite have suffered pneumatolysis with the introduction of pyrrhotite, tourmaline and fluorite. This part of the granite is much poorer in biotite than the granite exposed elsewhere in the area, and contains microcline microperthite which is the last mineral to crystallize from the granite intrusion, since it often poikilitically encloses crystals of quartz, and also occurs in some of the veins cutting the granite.

The micrometric analysis in Table 3 is representative of the granite in the Powelltown district, being obtained from thin sections of samples from six localities; that of the You Yangs (1, p. 128) is added for comparison:—

TABLE 3.

—	I.	II.
Quartz	32·0	28·7
Orthoclase	34·7	34·8
Plagioclase	25·6	25·5
Biotite	5·7	8·8
Accessories	2·0	2·2

I.—Granite, Powelltown.
II.—Granite, You Yangs.

Although the mineral percentages are very similar for the two examples, variations occur in that the You Yangs granite is a soda-rich type and contains minerals like microcline, orthite and hornblende not recorded from the more normal portions of the potash granite from Powelltown. The amounts of orthoclase, plagioclase and accessory minerals in each type, however, are remarkably similar.

Table 4 illustrates the variation in the heavy minerals of the granite, sampled portions treated for heavy mineral analysis being obtained from Nayook West, Gembrook, Bunyip, Powelltown, Mount Beenak, Garfield and Tynong. Separation into light and heavy fractions was effected in bromoform of specific gravity 2.88. The index number is lowest for pneumatolysed portions from the quarry at Nayook West, and highest at Mount Beenak where slightly more biotite has been produced from rather

greater assimilation of xenoliths. The average index number for the three Powelltown localities (i.e., Powelltown, Nayook West and Mount Beenak) is 4.4 and the average specific gravity is 2.64, these figures being comparable with those obtained from the granite outcropping at Gembrook and Bunyip.

The heavy mineral indices and assemblages obtained from localities outside the Powelltown area are added for comparison, and it is seen that at Garfield and Tynong the granite has higher index numbers because local assimilation of included rock fragments has been greater, and basic clots and schlieren are more abundant. The variation in the index numbers is due to the generation of varying amounts of the ferromagnesian minerals consequent upon xenolithic digestion, but the primary accessory minerals, like zircon and apatite, remain fairly constant in amount and character throughout this granite massif.

TABLE 4.

	I.	II.	III.	IV.	V.	VI.	VII.
Index Number	1·8	4·7	4·8	4·8	6·5	10·1	10·3
Specific Gravity ..	2·61	2·63	2·64	2·64	2·66	2·66	2·64
Actinolite	..	..	..	..	V	..	..
Apatite (colourless) ..	o	C	o	C	o	C	C
„ with pleochroic cores	..	..	V	V	V	..	r
Biotite	C	A	a	A	A	A	A
Chlorite	a	C	C	o	o	o	o
Epidote	..	V	..	V	..	V	..
Fluorite	V	..	..	V	..	..	V
Garnet	..	V	..	V	V	..	V
Hornblende	..	V	a	..	..	a	C
Ilmenite	o	r	r	C	C	o	V
Orthite	..	..	..	..	..	..	V
Pyrite	a	V	..	V	V	..	o
Rutile	..	..	..	..	..	V	..
Sphene	o	r	o	..	..	o	o
Topaz	..	V	..	..	..	V	V
Tourmaline	V	V	r	V	..	..	..
White Mica	r	V	V	V	V	V	V
Zircon (colourless) ..	o	C	o	o	C	C	C
„ (pale yellow) ..	V	r	..	o	r	V	V
„ (inclusions in) ..	o	o	C	o	o	a	a
„ (zoned)	r	r	o	V	r	o	o
„ (corroded) ..	V	V	..	V	V	r	..
„ (water clear) ..	V	V	V	V	V	V	V
„ (parallel growths)	..	..	..	..	V	V	..
„ (acicular) ..	V	V	..	V	V	V	V
„ (asymmetrical) ..	..	V	V	V	V	V	V
Zoisite	..	V	..	..	..	V	..

A = very abundant; a = abundant; C = common; o = occasional; r = rare; V = very rare.

I.—Nayook West.
II.—Gembrook.
III.—Bunyip.
IV.—Powelltown.
V.—Mt. Beenak.
VI.—Garfield.
VII.—Tynong.

XENOLITHS.

The xenoliths in the granodiorite are all sedimentary xenoliths, and present various stages in the contact metamorphism of the Silurian rocks. In schistose and foliated examples, the banding

arises from the parallelism of alternating laminae of biotite and quartz; this may be due to the original heterogeneity in the sediment as suggested for banded hornfelses (8, p. 64), or to stretching and flow banding resultant upon the movement of the hot plastic xenolith in the magma.

Microscopical examination shows that the xenoliths in the granodiorite may be either siliceous, aluminous, or characterized by actinolite, by biotite and plagioclase, or by biotite and orthoclase.

The siliceous xenoliths consist essentially of granular quartz and diopside; grains of sphene are common, actinolite surrounds some of the diopside crystals and may indicate the initial conversion of pyroxene to amphibole, a reaction produced during the cooling of the rock, and representing re-adjustment to conditions of lower temperature (8, p. 35); apatite, rutile, muscovite, rounded zircons, pyrite, pyrrhotite, orthoclase and plagioclase also occur. The rocks in this group represent schistose diopside quartzites which have been subjected to more severe metamorphism than they experienced as contact rocks, so that coarser-grained textures and alignment of the constituents have been produced.

The aluminous xenoliths are schistose and foliated inclusions with variable amounts of spinel, corundum and sillimanite. They represent an early stage in the alteration of aluminous sediments. The spinel occurs in clusters and strings of idioblastic crystals (5, p. 38) similar to those occurring in silica-poor hornfelses (8, p. 44); it is the deep green pleonaste variety, and its presence marks the rock as one deficient in silica. Although free quartz is present in the same rock section as spinel and corundum, these two minerals are never in direct contact with the quartz, some of which has been introduced from the granodiorite magma. This occurrence of spinel and quartz together in xenoliths, indicates a lack of equilibrium and a limited condition of diffusion which is rapidly passed when mechanical disintegration of the xenoliths begins (3, p. 366), and with increased granitisation of these xenoliths, spinel and corundum are eventually changed to felspar. Read suggests that spinel-corundum xenoliths belong to the silica-poor members of the argillaceous-calcareous hornfelses, and that the surplus alumina of the sediments gave rise to the production of spinel (6, p. 449). Spinel-corundum xenoliths in the Powelltown district are considered to have arisen in like manner, being of sedimentary origin.

The corundum occurs as irregular crystals both patchy blue to colourless and deep blue (sapphire) in colour. It has been produced in the absence of free quartz from rocks relatively rich in sericite, and frequently occurs as idioblasts embedded in a granular matrix of orthoclase. The corundum has been

partially altered to a micaceous product containing irregular relics of the fresh mineral as also observed elsewhere (6, p. 447), and both the corundum and the spinel occur as armoured relics, the protective barriers around them being biotite, muscovite, sillimanite and orthoclase.

Iron ores, limonite, rounded zircons, rare oligoclase, zoisite and sphene are also present in the aluminous xenoliths. Orthoclase is poikilitic in examples which have been subjected to more advanced grades of metamorphism, and it includes abundant apatite rods. In some examples, pneumatolytic tourmaline and pyrite, and rare crystals of zircon have been introduced from the granodiorite.

The xenoliths characterized by the presence of actinolite consist of plagioclase, actinolite containing rare residual grains of augite, biotite, abundant apatite, lobate growths of quartz in optical continuity, ilmenite, rounded zircons, rare rutile and zoisite. They were formed from sediments containing small amounts of lime originally.

The biotite-rich xenoliths consist of two types, one in which plagioclase felspar is dominant, and another with orthoclase as the dominant felspar; in each of these types, quartz and biotite are about equally developed. They were produced from sediments which initially contained equivalent amounts of silica and alumina, but varying amounts of potash. The biotite-rich plagioclase xenoliths form the most abundant inclusions in the granodiorite; they are dark and fine-grained, having biotite arranged in decussate structures. The granodiorite adjacent to these xenoliths contains xenocrysts of rounded zircon and rutile, whilst orthoclase and plagioclase are often poikilitic and the plagioclase crystals are sometimes zoned with remnants of xenolithic material. Some of the biotite in the granodiorite close to the xenoliths, and much of it in the xenoliths, is sieved by quartz, and occasional ocellar structures have been formed where the biotite was forced aside by growing crystals of quartz.

The biotite-rich orthoclase xenoliths were originally sediments poor in chlorite, but they apparently possessed abundant sericitic material; with advancing metamorphism, muscovite and subsequently orthoclase were produced from the sericite.

Xenoliths in the granite at Powelltown are of sedimentary and igneous origin. Amongst the sedimentary xenoliths, only two types have been recognized, the biotite-rich plagioclase xenoliths and the biotite-rich orthoclase varieties which are like those in the granodiorite except that most of them are more granitised. The xenoliths of igneous origin in the granite are reconstituted granodiorite; they contain large zircons with well-defined crystal faces and the grain size varies from fine to medium. Large plates of biotite contain haloes and inclusions as numerous as those

in the main mass of the granodiorite, and they have a definitely igneous aspect in contrast to biotite crystals developed from the alteration of the sedimentary rocks, where they always occur as small laths, often in decussate arrangements, or as elongated shreds.

Summary and Conclusions.

Two plutonic intrusions invaded Silurian sediments in the Powelltown district, one of them being granodiorite intruded as a stock, and the other a granite of batholithic nature. The limited field evidence indicates that the granite is the younger of these two intrusions.

Accidental xenoliths from both of these igneous masses have been grouped according to the main variations in composition as reflected by the mineralogical associations. Different textures have been produced in the xenoliths corresponding to the different degrees of thermal metamorphism to which they have been subjected. The fact that xenoliths in the granite are more granitised and drawn out into schlieren than corresponding types in the granodiorite, which often still retain traces of sedimentary structures, lends support to the conclusion that the granite is the younger of the two intrusions.

There has been no sedimentation or igneous activity between the late Devonian or early Carboniferous intrusive period and the deposition of Recent hillwash and alluvium. Agents of erosion must have been actively at work throughout this time to have removed practically all of the Silurian cover and expose and dissect the underlying granitic rocks.

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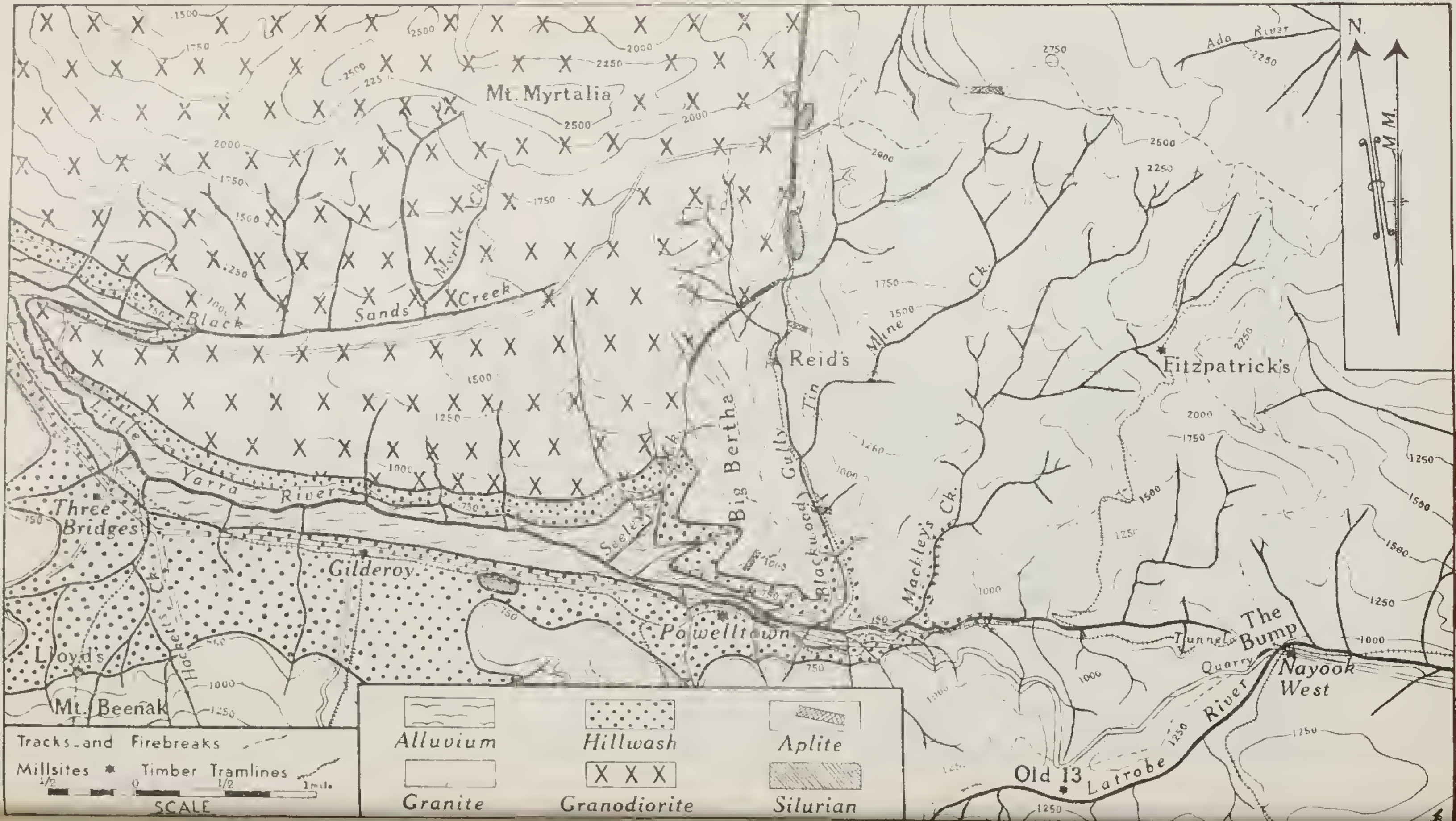
N.
M.M.
Ada River
Mt. Myrtalia
Myrtle Ck.
Sands Creek
Black
Little Yarra River
Three Bridges
Gilderoy
Hocketts Ck.
Lloyd's
Mt. Beenak
Reid's
Tin Mine Ck.
Big Bertha
Seeley's Ck.
Blackwood Gully
Powelltown
Mackley's Ck.
Fitzpatrick's
Tunnel
The Bump
Quarry
Nayook West
Latrobe River
Old 13
Tracks and Firebreaks
Millsites
Timber Tramlines
SCALE
1 mile
Alluvium
Hillwash
Aplite
Granite
Granodiorite
Silurian

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Art III.—*The Physiography of the Echuca District.*

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I. Introduction.

At first sight the wide-spread plains of northern Victoria and southern Riverina do not suggest physiographic problems, but closer examination shows several interesting features in the area of which the town of Echuca is the centre. The most evident of these features is the great bend the Murray River makes to the south when about 30 miles north-east of Echuca, but this is only one of many associated features which give a physiographic unity to the district.

The area treated in this payer is a strip about 70 miles long, extending from south-east of Rochester (Victoria) to Deniliquin (N.S.W.). The width of the more important part of the strip is only a few miles, though for its study a greater area has to be included in the northern part so that the general map has something of the shape of a tau cross.

II. Previous Workers.

As far as the writer is aware no general account of the area has been published. Gregory (1) in his Geography of Victoria mentions the bend of the Murray to the south and explains it by saying that the river has here cut through the raised flood plain which borders it further east. The problem is more complex than this explanation would lead one to infer.

The New South Wales Lands Department has published a plan of part of Riverina District, extending from Wagga to Balranald, on a scale of 4 miles to the inch. Generalized contours are shown at vertical intervals of 5 feet and provide a key to

the understanding of the area. On the Victorian side the State Rivers and Water Supply Department has prepared parish plans of irrigable districts with 1-ft. contours and with spot heights shown to 1/100 ft. at intervals of 5 chains or closer if necessary. These plans, on the scale of 20 chains to the inch, are as accurate as could possibly be desired for the study of drainage problems since they have been prepared for that special purpose. From their vertical scale the plans necessarily cannot represent higher areas but in such areas detailed levels are not required for our present purpose. The fact that plans can be prepared on such a scale gives a good idea of the general flatness of most of the area. In one part—north of Corop and north-west of Lake Cooper—no detailed survey was made as this part of the district was unsuitable for irrigation, the northern portion especially being low-lying and swampy.

It is possible that among the professional papers of the Victorian Water Supply Commission there may be reports which contain information or theories regarding the area but I have seen none.

Many of the physiographic features of the Victorian portion of the area, such as the condition of Lake Cooper when settlement first reached the district, the low banks of the Murray at Barmah, and the course of streams across the line of the Bama sand-hill are mentioned in an account of early settlement written by E. M. Curr (2) who made several journeys from Colbinabbin to the Murray River nearly a century ago and who was the first settler on the lower Goulburn.

III. Acknowledgments.

I wish to acknowledge my debt to the N.S.W. Irrigation Commission (Sydney) for the map of Riverina already mentioned, and to the engineers in charge of the Victorian Water Supply Districts of Rochester (Mr. H. E. Harding) and Tongala (Mr. C. Gallop) for assistance with plans and for giving me the benefit of their thorough—and probably unique—knowledge of the drainage of those districts. My attention was directed to the study of the subject by a conversation some years ago with Mr. A. S. Kenyon.

As on every other occasion when I have needed assistance, Mr. W. Baragwanath, Director of the Geological Survey of Victoria, and his officers have done all in their power to help me. This help has been particularly valuable in the preparation of the plans, etc., which accompany this paper.

IV. General Physiography.

A glance at a map of south-eastern Australia shows that the Murray River marks a very definite drainage line. Its southern tributaries flow into it more or less at right angles, though usually directed downstream (particularly in the case of the Goulburn)

GENERAL MAP OF ECHUCA AREA

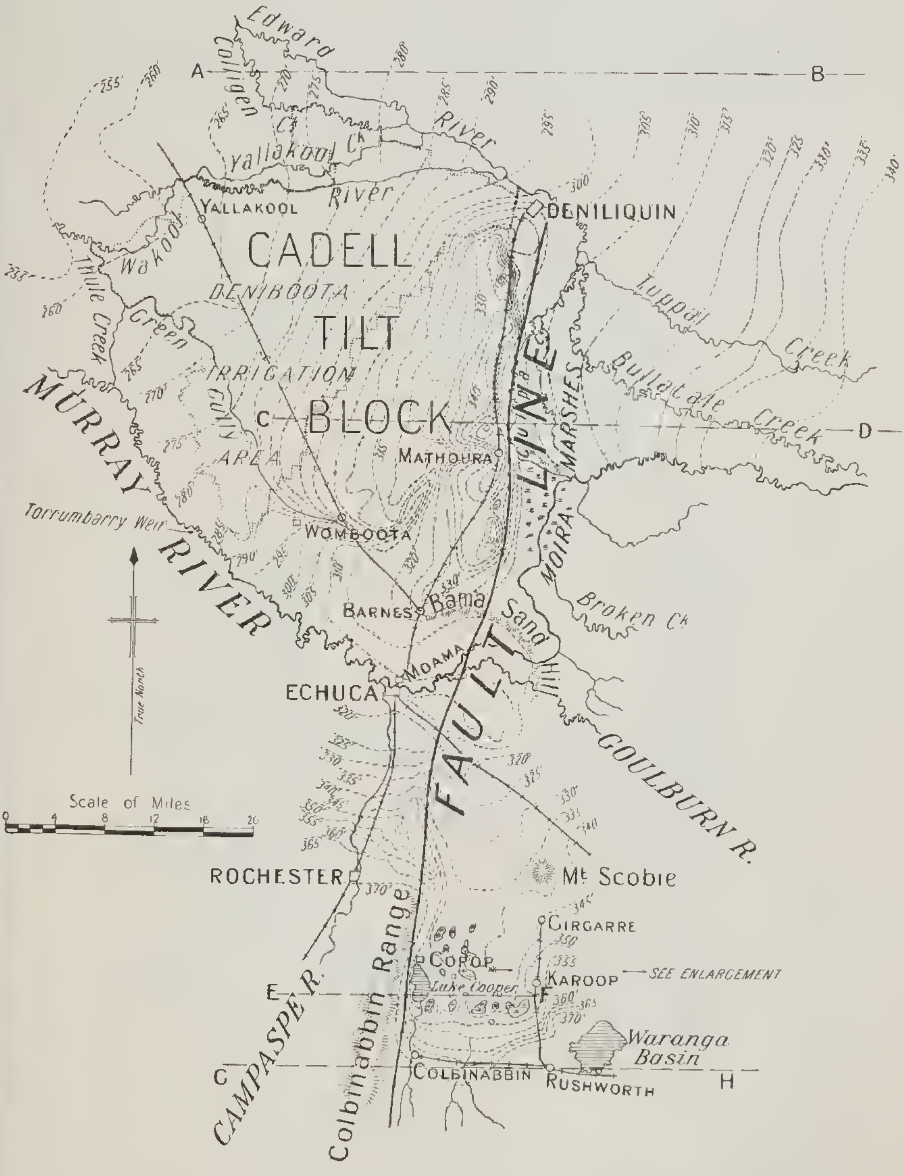

Fig. 1.

before actually entering it. North of the Murray the general direction of tributaries is from east to west and the Murray has numerous distributaries, some of which are permanent streams, while others flow only after the level of the main river has been raised by heavy rains or the melting of snow on the hills around its sources. The general direction of the contour lines in Victoria is east-west and in New South Wales north-south. In Victoria the general direction of these lines is broken by the presence of old rocks forming low hills between the various tributaries. Thus besides the hills which divide the upper Murray or Indi from the Mitta Mitta and the Mitta Mitta from the Ovens, we have the granite and Ordovician hills of which Futter's Range is the most prominent separating the Ovens from the Broken River, a spur of Silurian and older rocks between the Broken and Goulburn Rivers, culminating in the diabases and associated rocks of the Dookie Hills, the Colbinabbin Range between the Goulburn and Campaspe and the granite masses of the Terricks, Pyramid Hill and Mount Hope between the Campaspe and the Loddon. A minor spur runs parallel to the Colbinabbin Range but further east and is important for our present paper as it forms the eastern boundary of the Lake Cooper drainage basin. It is composed of the Silurian hills of Rushworth and is represented about sixteen miles further north by the isolated hill of Mount Scobie, also probably Silurian, which rises like an island above the level of the surrounding plains.

Several striking features break the regularity of the Murray plains:—

(1) The Murray River, east of Mathoura (N.S.W.), gives off two important distributaries to the north—the Edward River and Gulpa Creek—and then at the "Mathoura Bend" turns to the south as a stream of altered character till it approaches the Goulburn when it again takes a westerly course.

(2) West of this north-south reach and of the Gulpa Creek which continues the line to the north is a raised area 30 feet and more above the streams and sloping gently to the west. Not a single stream crosses it.

(3) East of the edge of this "Cadell Tilt-block" is an area of swamps and lagoons, interspersed with low sand ridges—the Moira Marshes—through which the Murray flows.

(4) South of the Murray the drainage from a large area between the Campaspe and Goulburn Rivers fails to establish a definite drainage channel to the Murray, and collects in Lake Cooper and its associated swamps making its way to the Murray in wet seasons either through ill-defined water courses or through artificial channels.

(5) Between the Lake Cooper area and the Campaspe River the Colbinabbin Range runs from south to north forming the western boundary of the Lake Cooper basin, which is separated

from the Goulburn basin to the east by the Rushworth Hills, and, further north, by a divide rarely recognizable in the field.

V. The Cadell Tilt-Block.

This name is applied to the triangular area of land between the Edward and Murray Rivers, the eastern base rising from the Murray River and Gulpa Creek, the southern side bounded by the Murray below Echuca and the northern by the Edward River and ana-branches which meet the Murray round the apex to the west

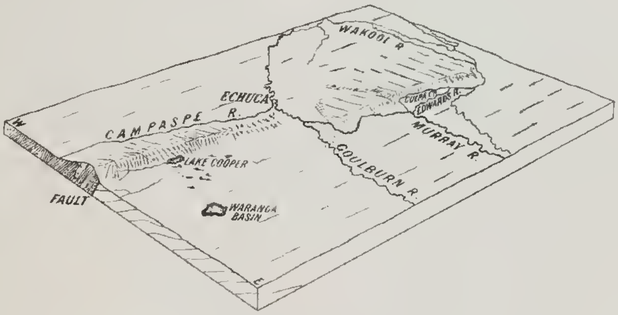

FIG. 2.—Block diagram of Area.

E. S. Hills Photo. *E. D. Service del.*

FIG. 3.—Culpa Creek south of Mathoura, showing steep bank on the western side.

From Yarrawonga to a point a few miles east of Mathoura the Murray pursues a general westerly course. It is very tortuous and cut-off meanders in all stages of evolution may be noticed. A good example is "Nine Panel Bend," a few miles upstream from the offtake of the Edward River. The "nine panel" refers

to the length of fencing necessary to cross the narrow neck of land round which the river meanders. At Yarrawonga and Tocumwal the critical stage of flood level of the Murray is over 20 feet above the cease-to-flow level. Below Tocumwal cuttings through the right bank of the river divert water into the Tuppal and Bullatale (locally Bullatella) Creeks, which ultimately join the Edward River near Deniliquin. As the little settlement of Tarragon is approached the banks of the Murray become lower and outlets through them, though small, become more numerous. At last, just east of Tarragon, a large channel, though small compared with the Murray, breaks out to the north, doubling back somewhat as it leaves the parent stream. This is the Edward River. It widens into a sluggish stream as it flows north, and at last turns west-north-west around the northern edge of the Cadell Tilt-block. The distance from where it leaves the Murray to its most northern point near Deniliquin is about 30 miles in a straight line. About a mile downstream from the Edward off-take the Gulpa Creek also leaves the Murray. At first its banks are steep and its channel deep, narrow, and canal-like. Then it expands into the Gulpa Swamp, and for about 4 miles it has no defined channel other than a shallow artificial cutting through the centre of the swamp. Near Mathoura it again becomes a wide muddy shallow creek with low ill-defined eastern banks, but steep, in places vertical, western banks (Fig. 3). After a tortuous northerly course it joins the Edward south of Deniliquin.

From the off-take of the Gulpa to the Mathoura Bend the Murray is still tortuous, but its banks are low, and the variation between high and low water levels throughout the year would be about 10 feet. Although the banks are low, floods rarely cover them continuously, and the even level of water throughout the year permits the growth of willow trees along the banks, making of these reaches a beauty spot.

About 2 miles west of the Gulpa off-take the Murray swings to the south. For over 20 miles it retains its low banks, but is narrow and comparatively straight. From its narrowness and shallowness the stretch between the Gulpa and Barmah is known to rivermen as the "little river." It is bordered by swamps which receive water through numerous small breaks in the bank of the river. The larger swamps, though shallow, may retain water throughout the whole year, and are known as the Moira Lakes both on the Victorian and New South Wales sides. Near Barmah the river regains its earlier character and turns west towards Echuca, being joined by the Goulburn River 7 miles east of the town.

The area between the Murray and Edward Rivers, as has been already stated, is crossed by no streams. The surface soil is a yellowish loam or clay though there are areas of grey loam

and some sandy rises. Its present undulating surface is partly due to modifications caused by rain wash, but there are well-marked tortuous depressions with a general east-west direction. The best-marked of these is shown on the map, trending south-west from near Mathoura, then north-west past Womboota, and ultimately merging into Thule Lagoon which is connected with the Murray. Where this depression is best shown it is a wide shallow valley with relatively steep sides, and with every appearance of being a disused, partly infilled river course. It is known locally as Green Gully.

The 350-ft. contour line runs along the eastern edge of the Tilt-block through Mathoura where the uplifted block reaches its greatest height—over 360 feet above sea level. The general height of the eastern edge of the block may be taken as 340 feet. Upstream along the Murray the 340-ft. contour line crosses the river near Tocumwal, 30 miles east of Mathoura. At the western edge of the Tilt-block the height is about 260 feet. The discussion of the significance of these features is postponed till later in the paper.

VI. The Moira Marshes.

The area between the Bullatella, Gulpa, and Murray, and the corresponding area on the Victorian side of the Murray is a region of sand ridges and swamps though there are considerable areas of relatively high land with a loamy soil. The numerous creeks are sometimes bordered by narrow banks above flood level, but on the other hand often widen into swamps and form a maze through which only an experienced bushman can find his way. The sand ridges are striking features in such country and seem often to be independent of the present drainage system. They will be briefly referred to later. Many of the swamps are apparently deserted stream courses, but others are wide expanses such as the Moira lakes which represent the lowest portions of a depressed area.

VII. The Colbinabbin Range and Lake Cooper.

The Colbinabbin Range stands out prominently on the geological map of Victoria, its colour, green for Heathcotian, showing up distinctly. The published maps show it as ending east of Elmore, but this is incorrect and mss. corrections are shown on some old maps. The rocks of the range may be traced on the low hills for some miles further north and are buried below the surface soil of the plains east of Rochester.

The geology of the range is not important for our purpose but as no account of it has yet been published, except for the part near Heathcote, a very brief summary of the geology of the northern part may be given.

The core of the range consists of diabase and cherty shales placed by Thomas (3), who has studied these rocks near Heathcote, as Middle Cambrian or older. On the west between Elmore and Colbinabbin (west of Allot. 122, Runnymede) shales yielded spicules of Protospongia (Harris and Thomas). These are the only fossils yet found in the area. Along the western side of the range fine-grained mudstones and cherty shales predominate, apparently of the Goldie Series (Upper Cambrian) of Thomas (3, p. 92).

These are well shown in road cuttings near Allots. 119, 130, and 206B, Corop, and in the north-west of Allot. 174, Nanneella. The diabase core of the range is in places massive and undecomposed as around Mount Burramboot (Allots 1, 5, Burramboot, and 40, Colbinabbin). The slopes of the range west of the Burramboot East state school show (quarry in Allot. 23, Burramboot and west of this) a succession of interbedded cherts and diabase, the latter being little altered on the hill slopes, but weathered to a greenish clay in the quarry. Near by, fragments of what may originally have been ash can be found. Jasper is a common associate of the diabase and is well shown along the north-south road between Allots. 63 and 65, Corop, and in the extreme north-west corner of the Parish of Burramboot. Fragments are common at other localities as in Allot. 7B, Corop.

The eastern slope of the Colbinabbin range is much steeper than the western and, lying about 2 miles east of the crest and 200 feet or more lower, is Lake Cooper, a shallow sheet of brackish water about 4 square miles in area. It receives the drainage of the Cornella Creek from the south but has no permanent outlet. It is only the largest of a number of similar depressions, most of which dry up in summer. In winter and after a succession of heavy rains the water level in Lake Cooper rises but most of the surplus water, instead of overflowing to the north, takes a parallel course east of the lake through an ill-defined series of swamps, and finally reaches the Goulburn or the Murray through channels partly natural and partly artificial. In fact the present drainage is regulated largely by a series of channels cut for the purpose. The Wanalta Creek further east uses the same intermittent drainage channels but has no lake along its course. It is a coincidence that the creek flowing into Lake Cooper is the Cornella (on some maps, Corneela), the main flood channel is the Cornelia Creek, while just across the Murray are Coronalla parish and Cornalla or Canally Station—all probably variants of the same native word.

The eastern boundary of the Lake Cooper-Cornella Creek depression is, the "Rushworth Pene-plain" of Silurian rocks. Due north, rising as a hummock from the level and swampy plain is Mount Scobie, a low sandstone hill on which the writer obtained a few indeterminate corals, crinoid and brachiopod fragments which enable one to place it as almost certainly an outlier of the Rushworth beds.

North-west of Lake Cooper the edge of the higher country is represented very accurately by the main Waranga-Mallee irrigation channel which, through the mapped area, runs between the 375- and 365-ft. contours till it crosses the Campaspe River north of Rochester. Even further north, to within 5 or 6 miles of Echuca, the western edge of the depressed area is noticeable from the contour lines, which for over 10 miles north of the Waranga-Mallee channel near Rochester still run north and south and close together though showing a slope of only 10-20 feet. The wider divergence of these lines immediately to the north-east of Rochester is due to the fact that the Campaspe River breaks out across this stretch of country in flood time, using the Cornelia Creek channels for its surplus water.

VIII. Origin of the Lake Cooper Drainage Basin.

The swamps around and including Lake Cooper may be divided into two classes. Most of them, including Lake Cooper itself, occupy the lowest parts of the drainage areas of creeks flowing from higher ground further south—depressions which the water must fill before it finds its way further north—but some cannot be explained in this way. In the north-west of the Parish of Carag Carag and the north-east of the Parish of Corop are depressions which receive only local drainage but which are noticeably lower than the general level of the surrounding country. The best marked of these depressions are the Salt Lake, Green's Swamp, and an unnamed group of swamps in Allots. 38-40 and 50-53, Carag Carag. These are seemingly not connected with the main drainage problem, and the theory now to be advanced to account for the formation of the whole depression is strengthened by the existence of these isolated areas 20 feet or more below the general level.

It is suggested that two causes have operated in forming this region. Firstly, it is postulated that there has been down-faulting in recent times of the area east of the Colbinabbin Range. No direct evidence of faulting is visible here though further south near Heathcote faulting has been an important factor in determining rock relationships. There is no evidence that any of the Heathcote faults are recent; in fact most of them are geologically old and have no physiographic effect saving that which arises from the unequal hardness of strata. However near Bendigo (4) and west of Guildford (5) comparatively recent movement has been demonstrated to have taken place along old fault lines.

The unsymmetrical slopes of the Colbinabbin Range, as shown in the section (Fig. 6), and the low level of Lake Cooper and its drainage basin, as compared with both the Campaspe on the west and the Goulburn on the east, seem to point to factors other than normal erosion. The Campaspe at Elmore is 430 feet above sea level, the Goulburn to the east is 384 feet, while the swamps

around Lake Cooper are at 340 feet, the surface of the lake a few feet lower, Salt Lake at 320 feet (and isolated) and the general

MAP OF AREA AROUND LAKE COOPER

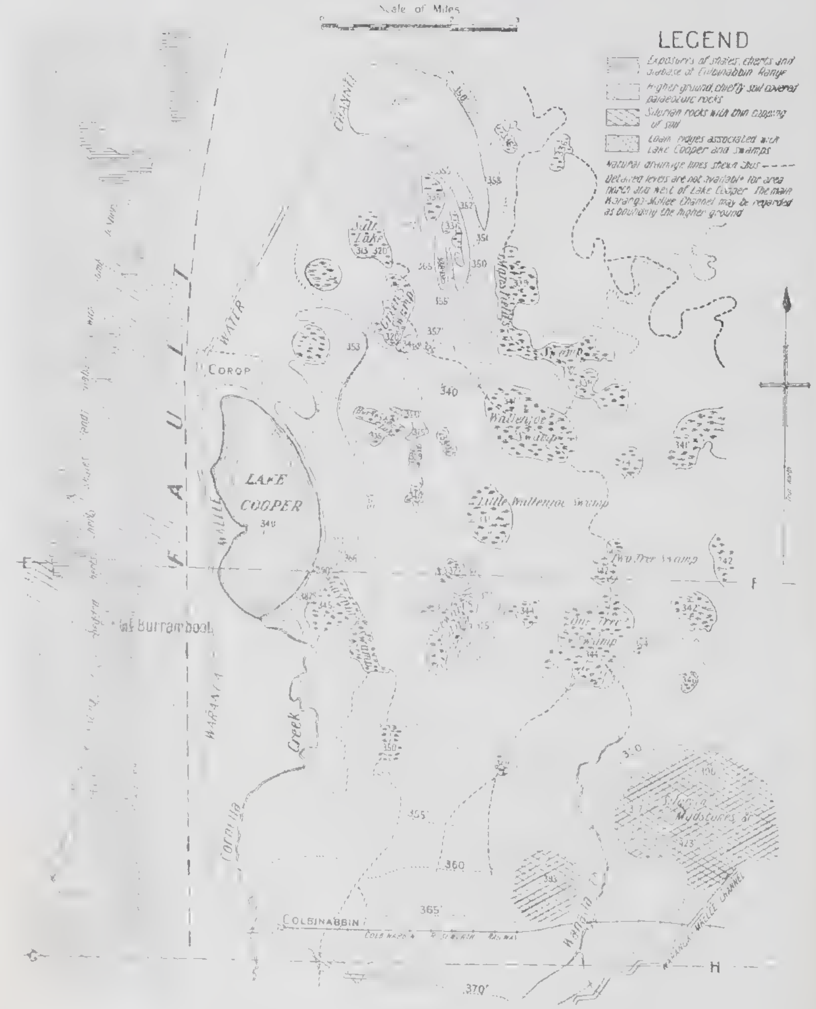

FIG. 4.

level of the surrounding plains between 340 and 350 feet. Lake Cooper is thus about 100 feet below the level of the Campaspe River at Elmore.

The physiographic features just described both south and north of Echuca can be explained if a south-north fault is postulated as running from west of Lake Cooper north to Deniliquin. In the south the result was the down-faulting of the Lake Cooper basin by perhaps 50-100 feet or even more. In the north the

Cadell Block was raised and tilted downwards to the west, the throw of the fault here being rather less than further south. Near Echuca where the movement hinged, as it were, there was little displacement and so the water of the Murray was enabled not only to find its way round the north of the raised block, but also to find its way round the south. For purposes of reference this fault may be referred to as the Cadell Fault. North-south faults are of common occurrence in northern Victoria, and at least in the two cases already mentioned—the Whitelaw fault east of Bendigo and the Muckleford Fault west of Guildford—recent movement along such a fault line seems proved. The present case would be a third example of this.

IX. Swamps in the Lake Cooper Depression.

While faulting is probably the chief agent in forming the Lake Cooper depressed area it does not fully account for some local features. These are depressions surrounded by loam ridges and not connected with the main drainage system. The best examples occur north-east of Corop. To examine this area the Corop-Stanhope road may be followed for about 3½ miles east from Corop, and a turn north then made between Allots. 93 and 94, Carag Carag. A shallow channel from the Wallenjoe Swamp

W. J. Harris Photo. *E. D. Service del.*

Fig. 5.—Lake Cooper from Colbinabbin Range. Mount Burramboot on extreme left (looking north-east).

crosses the road and, running to the north-west, enters Green's Swamp through a gap in a loam ridge. The ridge on either side of the gap rises to a height of 30 feet or more above the general level. The gap is steep-sided, but why a stream should cut such a gap is not evident since the swamp it drains had apparently another and easier outlet to the north-east. Following the road north one crosses the loam ridge which here bifurcates, one branch running to the north-east and the other slightly west of north. After the ridge is crossed a descent is made to an enclosed depression which contains three small swamps. These are merely

the lowest portions of the depression and derive their water from the surrounding slopes. The road passes through the centre of one swamp and, among the material ploughed up to form the road, may be seen nodules of earthy limestone. The presence of these nodules suggests that the actual position of the swamps may have been partly determined by the removal of limestone from the subsoil by solution. and the consequent sinking of the surface. Similar nodules occur round Lake Cooper itself and also around Salt Lake, and in other parts of the district.

The loam or clay ridges are difficult to explain and no satisfactory explanation occurs to the writer. The ridges rise to a height of 50 feet or more above the depressions in some cases, and are not composed of sand but of a yellow or brown clayey loam which when dry crumbles easily, but when wet would form a sticky mass. In addition to those already referred to an almost semicircular ridge flanks the eastern edge of a swamp in Allot. 107, Corop. (This swamp when dry is a practically level area of brackish silt.) The best marked ridge flanks the eastern edge of Lake Cooper (Fig. 4). It may be that these ridges are composed of silt blown from the depressions by west winds during a former long arid period, but this explanation does not seem fully satisfactory. The presence of remains of large trees in the bed of Lake Cooper, especially in the northern part, would indicate that the lake, if not formerly dry altogether, must for long periods have been smaller than at present, but since white settlement in the district a hundred years ago it seems to have contained water in most years. When E. M. Curr first traversed its bed in 1841 he described it as a grassy plain of wild carrot (2). P. Chauncy, in a letter to Brough Smyth dated 1873, brought under my notice by Mr. W. Baragwanath, states that he saw the lake dry in, he thinks, 1858, but his mention of this one instance would imply that this was very unusual. Old residents state that oat crops have been sown on the lake floor, and there is a report that it was dry about 1930. Large dead red gum trees (Eucalyptus rostrata), not yet stripped of small branches, are also found in the present channel of the Edward River east of Mathoura. A study of the lakes and associated loam ridges of the Kerang-Swan Hill district may throw light on the origin of the Lake Cooper ridges. Apparently similar silt hills are found on the southern and eastern sides of many of the shallow lakes in the Camperdown district, and are mentioned in Memoir No. 9 of the Geological Survey of Victoria. They are explained (p. 9) as being formed by silt blown from the dry beds of these lakes in summer. The explanation given there of the enlargement of Lake Colongulac may apply to Lake Cooper.

The Salt Lake occupies the lowest part of a depression even lower than Lake Cooper, and with a barely perceptible slope. The amount of brackish water varies according to the season, but the slope is so gentle that a sample of water free from mud cannot be

obtained without wading into the water. The shores of the lake are littered with fragments of earthy limestone as already mentioned, so that it is feasible to suppose that in this and other cases the actual position of the deepest portion of a depression may have been determined by solution. Like Lake Cooper, Salt Lake was probably often dry till irrigation channels were made through the district.

X. Sand Hills and Gravel Deposits.

Insufficient work has been done on this subject to warrant a lengthy discussion. The following facts may be stated:—

(1) Gravel deposits apparently derived from granitic rocks and not thoroughly waterworn occur at several localities, the best-known in the Echuca district being about 2 miles north of Moama, the New South Wales township on the opposite bank of the Murray to Echuca. This particular deposit is roughly stratified, and is comparatively free from iron staining. It may represent the partially re-sorted capping of a buried granitic mass such as Mount Hope or Pyramid Hill. As far as can be ascertained its thickness has never been proved by boring, possibly because the deposit, which is used for road-making purposes, could not be worked profitably below the level of the water in the Murray near by. Similar gravels, usually ironstained, are found in many places along the Murray, but are usually limited in extent, and most likely are coarse river-gravels. I have heard it stated that a bore a few miles south of Mathoura bottomed on granite at a depth of possibly 200 feet or so, but I have been unable to verify the statement which in itself does not seem at all improbable.

(2) Sand hills of much finer iron-stained material are widely distributed. They are antecedent to the present drainage system and are possibly records of an earlier more arid period. The sand consists chiefly of small fragments of glassy silica and is evidently wind-borne. The evidence shows that these deposits are older than the present river courses as the Murray, Goulburn, and Campaspe all cut through sand-hills. The best-marked ridge is known as the Bama Sand-hill, a ridge which runs for about 7 miles in a generally easterly direction from near the Barnes railway station on the Echuca-Deniliquin railway to the Murray west of Barmah (Victoria). It there turns to the south, crosses the Murray into Victoria, and is continued across a depression near Madowla, and then across the Goulburn. E. M. Curr (2) marks the Victorian part of this ridge on his map as the "Towro Sand-hill," and states that he had often speculated on the reason for its independent direction, but he gives no indication of his conclusions. The Bama Sand-hill is only the most prominent of a number of similar ridges, a second ridge being cut through by the Goulburn just before it enters the Murray, and a third being

cut by the Campaspe and Murray near Echuca. These sand hills are quite distinct from the Lake Cooper loam ridges. Before leaving this topic attention may be called to the sand ridge which flanks the northern edge of the Gulpa Swamp. (For such ridges to flank swamps is not at all unusual.) This is composed of similar material to the Bama Sand-hill, but is lower. It, too, seems to be older than the low-lying land which encloses it, and its continuation is possibly to be found in loamy ridges south and south-west of Mathoura. These, being on the raised side of the Lake Cooper-Cadell fault line, have been denuded so that the material exposed at the surface is a sandy loam rather than sand.

XI. Physical Features and Irrigation.

The structure of the area has determined the course of irrigation channels through it. The Waranga Basin, fed from the Goulburn River, commands the area in Victoria between the Murchison-Colbinabbin railway on the south and the Goulburn River on the north, but as the level of the Basin is shown as 388 feet above sea level, it will be seen that it was necessary to make the main western channel skirt the Colbinabbin Range, so that it runs almost due north from Colbinabbin to a point east of Rochester, and then turns once more west. Water from it is unavailable for the district west of the range and south of Rochester.

In New South Wales the Cadell up-lift makes irrigation impracticable by gravitation for any but limited areas of the western portion of the Cadell Tilt-block, but a scheme is at present being worked out by which a supply of water, diverted from the Murray River at Yarrawonga, will be led across the Edward River at Deniliquin and made available for the western and lower portion of the area. The eastern boundary of the proposed irrigation area roughly follows the 300-ft. contour line, but with the necessary fall. The scheme is known officially as the Deni-Boota Domestic and Stock Water Supply and Irrigation Scheme, the name being derived from the districts of Deniliquin and Womboota, though it would appear that only a small portion of the Womboota district will be in the irrigable area.

XII. Summary of Geographical History of the Area.

It is possible to construct a theory which will account for all the major geographical anomalies of the district, such as the Moira Marshes, the Cadell Tilt-block, and the inefficient drainage of the Lake Cooper region. The following is the suggested order of events.

(1) The Murray at an earlier period flowed west past Mathoura, probably just to the south of the township, and then across what we have called the Cadell Tilt-block. The depression

shown by the contour lines (Green Gully) marks this former course, and a detailed map would probably show minor tributaries and "lagoons" such as fringe the Murray at present. The large sand ridge north of the Gulpa swamp would be on the northern bank of this former stream and probably extended further west than it can be traced at the present day.

(2) Movement took place along a north-south line from near Deniliquin to somewhere near Toolleen (north of Heathcote) forming the eastern edge of the Cadell Tilt-block and the western edge of the Lake Cooper basin. It is probable that the changes were effected by a number of small displacements, possibly spread over a long period, and that the final result was that in the north the western block was raised and tilted rather than that the eastern side was depressed, as the Moira Marshes are not lower than the plains a few miles north of Deniliquin. In the south the result was the lowering of the Lake Cooper basin. Near Echuca there seems to have been little movement so that the Murray was able there to find its way across the fault line. The raising of the Echuca-Deniliquin block dammed back the Murray and formed the Moira Marshes. The Murray, faced with an obstacle right across its former course, divided, some of the water working to the north along the scarp till it found a way round in that direction, and some working to the south with the same ultimate result. The Edward, the Gulpa, and the "little river" would thus originate after the uplift. If the rainfall of northern Victoria averaged 4 or 5 inches a month the Moira Marshes would probably be converted into a shallow lake comparable with Lake George (New South Wales). That the area between Rushworth and the Colbinabbin range is a structural valley formed by sinking seems to be indicated by its low level. Even with a greater catchment and heavier rainfall it would probably be water-logged as the fall between Lake Cooper and the Murray at Echuca is only about 30 feet as compared with over 60 feet in the shorter distance between Rochester and the Murray along the line of the Campaspe. The surface of Salt Lake is practically at the same level as the banks of the Murray at Echuca.

(3) When the Murray flowed across the Cadell Tilt-block the Echuca-Koondrook stretch of the present Murray was possibly the lower course of its present tributary the Goulburn, though there is some evidence that the old Green Gully stream was joined by a large southern tributary west of Moira (New South Wales). As a result of changes of level the "little river" was formed, and the combined Murray-Goulburn then adopted the present main channel.

(4) The actual position of Lake Cooper and some of its associated swamps has been partly determined by the removal of calcareous material from the subsoil by solution, a process which led to local subsidence.

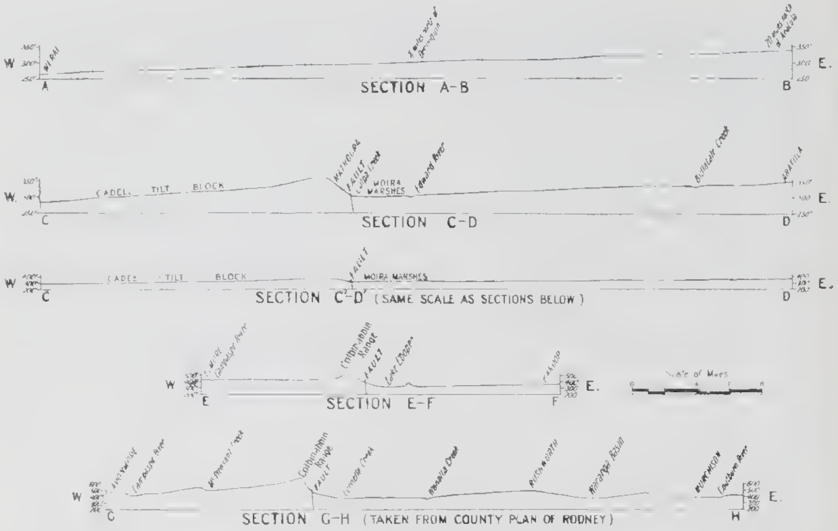

FIG. 6.—Profiles along section lines indicated in Fig. 1. All section lines are drawn to the same horizontal scale, but owing to the greater differences of elevation in the southern portion of the area the vertical scale of the two northern sections is greater than that of the two southern sections. For comparison Section C-D is drawn to both scales.

Section A–B.—This west-east section represents the general slope of Riverina north of the Edward River and beyond the influence of the Cadell Fault. The heights at both A and B are approximately the same as at C and D on the next section, but the slope is gradual and unbroken.

Section C–D.—Parallel to Section A-B but further south, showing the two similar slopes into which the general slope further north has been divided by the uplift.

Section C¹–D¹ is a repetition of Section C-D on the vertical scale used for the Lake Cooper sections.

Section E–F runs from Elmore across the Colbinabbin Range and Lake Cooper to the Rushworth-Girgarre railway at Karoop. The generally higher level of the western area, the drop to Lake Cooper, the loam ridge east of the lake and the featureless plain further east are shown. No figures are available for the height of the Colbinabbin range which is almost certainly higher than shown on this section.

Section G-H from Avonmore to Murchison has been drawn from heights recorded on the county plan of Rodney at approximately 1-mile intervals. Here again the height of the Colbinabbin range is underestimated as the plan gives heights along a road which passes through a gap in the range so that the highest reading on the plan is 1 mile west of the main ridge (626 feet). On the line of the range itself 588 feet is recorded, but the range is at least 100 feet above this. The difference in level between the eastern and western portions of the section is well shown. Near Rushworth Silurian rocks outcrop and the country rises generally.

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[Proc. Roy. Soc. Victoria, 51 (N.S.), Pt. I., 1938.]

Art. IV.—*Notes on the Physiography of the Geelong District.*

By ALAN COULSON, M.Sc.

[Read 9th June, 1938; issued separately, 23rd January, 1939.]

Introduction.

This paper discusses the following matters:—

(i) the altitude of the Otway Ranges in the Tertiary sea;

(ii) the post-Tertiary earth-movements and vulcanicity;

(iii) the development of the drainage system.

Altitude of the Otway Ranges in the Tertiary Sea.

The Jurassic rocks of the central portion of the Otway Ranges attain an altitude of 2,200 feet, and are flanked by marine Tertiary sediments of which the highest is about 900 feet. The Tertiary beds are limestone in the lower parts, and coarse sand in the upper.

This flanking relationship of the Tertiaries to the Jurassic was interpreted by Wilkinson (1865), Krausé (1874), Stirling (1901) and Hall (1911) to indicate that the Otways were an island of nearly 1,500 feet altitude in the Tertiary sea. Recently Hills (1935) has suggested that the Otways were completely submerged, and received a capping of Tertiary sediments, which was removed by denudation after the supposed post-Tertiary uplift. His objections to the earlier interpretation are:—

(*a*) absence of evidence of littoral facies in the Tertiaries;

(*b*) absence of evidence of existence of former shore lines;

(*c*) the deep dissection of the central portion of the Jurassics, which appears to be so vigorous as to indicate post-Tertiary uplift.

Regarding (*a*) it is true that littoral facies are rare in the Otway Tertiaries, though common enough in the parallel case of the Barrabool Hills, where the Tertiaries flanking the Jurassic have been shown (Coulson 1937) to contain pebbles of Older Basalt and (rarely) of Jurassic sandstone. The only instance of a boulder bed known in the Otway Tertiaries is at the base of the limestone of Alkemade's quarry, Kawarren, where a thin bed of Older Basalt pebbles can be seen. Three reasons may be advanced for the absence of littoral facies:

(i) the softness of the Jurassic gives a very short life to its detrital pebbles;

(ii) although the chances of Jurassic pebbles being included in the Tertiary limestone were fair, owing to the quiet water, they were remote in the case of the shallow-water Tertiary sands;

(iii) exposures of the contact between limestone and Jurassic are extremely rare, in fact, the author has not yet located one, whereas the contact of Tertiary sand and Jurassic can be seen at many places.

Regarding (*b*), the lack of evidence of the existence of former shore lines (this must also be admitted) and is more difficult to explain. The present shore line has characteristic rock-platforms, a few sandy pocket beaches at river mouths, occasional shingle beaches, and rare sea-caves. It is reasonable to suppose that similar features were developed at sea level in Tertiary times. Two possible explanations present themselves: (i) the sea-level in the Tertiary may have been steadily rising, as shown by the lithological change from limestone to sandy beds, and there may not have been a still-stand of sufficient duration to develop the features enumerated.

(ii) The features may have developed, and have since become obliterated by denudation. This is very likely on account of the softness of the Jurassic, and the rapidity of atmospheric and aqueous erosion in the area. Rock-platforms would become flat spurs, of which there are plenty in the ranges; the sand and shingle deposits of the beaches would be removed or obscured by vegetation, and the sea caves would in time collapse. Before the construction of the Great Ocean Road, several aboriginal shelter caves were known, but at the present time Ramsden's Cave (Hardy 1910) is the only one of any size above high water level.

Regarding (*c*) the deep dissection of the central portion of the ranges, the youthful appearance of the streams is due to rejuvenation by the post-Tertiary uplift, but, as will be shown later, they were initiated in Tertiary times when the Otways were an island.

A serious difficulty with the view of Hills is in the removal of the supposed universal capping of Tertiary sediments over the Jurassic. Such sediments would presumably be arenaceous like the present uppermost beds, and their thickness would be of the order of 1,500 feet. That every vestige of this great thickness of sandy beds should have been removed from the upper portions of the ranges is beyond belief; there would assuredly be large residuals of it, and the stream valleys would be choked with the practically indestructible detritus from the sand. But as is well known, the stream valleys in the higher Otways are singularly deep, steep-sided, and narrow, without alluvial flats. It is not

until after the 800–900 foot level is reached and the original Tertiary beds encountered, that the valleys widen out and become sandy. Clearly there never was a capping of Tertiary sediment over the Jurassic. Probably the marine sediments never exceeded the 900 foot level.

The theory of total submergence is therefore untenable, and the earlier view is retained here, that the Otway Ranges constituted an island in the Tertiary sea.

Post-Tertiary Earth Movements and Vulcanicity.

At the close of the Pliocene period and throughout the Pleistocene, the Geelong district suffered from a number of widespread shallow faults, and a few fold movements, and contemporaneous volcanic eruptivity on a grand scale. These processes have been dominant in determining the present topography.

It is probable that the general uplift of the whole area preceded the faults about to be described, and that it took place immediately at the close of the Upper Pliocene sedimentation. However, no great time interval elapsed before the faulting began, and probably differential stressing due to the uplift initiated it. The sketch map (Fig. 1) shows the main faults of the area.

FAULTS.

1. Rowsley-Anakie-Gheringhap fault.
2. Anakie-Lovely Banks fault.
3. Barrabool Hills-Curlewis fault.
4. Moolap-Leopold trough fault.
5. Corio Bay-Port Phillip Bay-Bass Strait faults.
6. Otway Ranges faults.

FOLDS.

1. Waurn Ponds Monocline.
2. Curlewis contorted beds.
3. Torquay and Anglesea anticlines.
4. Folding in the Otway Ranges.

1. *Rowsley-Anakie-Gheringhap fault.*

This pivotal fault commences in the Lerderderg district and extends 30 miles south through Rowsley and Anakie to Gheringhap. The maximum throw of 800 feet is at the northern end; it is about 500 feet at Anakie but disappears entirely near

Gheringhap. The fault has displaced Newer Basalt (Fenner 1918) of Pleistocene age, and is therefore late Pleistocene or even younger.

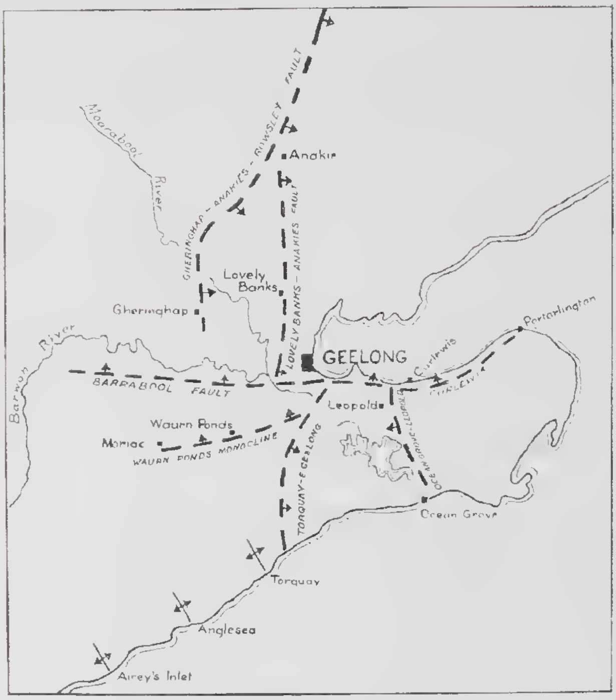

FIG. 1.- Faults in the Geelong District.

2. *Anakie-Lovely Banks fault.*

A normal fault commences at the central hill of the Anakies and extends nearly 20 miles south to near Fyansford Hill, running parallel to the Rowsley fault and about 5 miles to the east of it. The maximum throw of about 150 feet is in the middle section near Lovely Banks. Here again Pleistocene Newer Basalt has been displaced, the downthrow being to the east. The fault is therefore late Pleistocene or later.

3. *Barrabool Hills-Curlewis fault.*

The northern face of the Barrabool Hills is a demonstrable fault scarp, with a throw of 300 feet to the north near Ceres. The Barwon River flows along the fault line between Pollocksford and Fyansford. Originally noticed by Hall (1911), the fault was named the Barrabool Fault by Fenner (1918), and has been referred to as the Barwon Fault (Coulson 1930) but the prior name is here retained.

The western end of the fault begins near Pollocksford, and although the eastern end appears to be in Queen's Park, Fyansford, this is not the case, as the fault penetrates Newtown Hill and extends east to form the southern shore of Corio Bay, curving to the north-east near Curlewis and probably ending at Portarlington.

It is difficult to assign any age, other than post-Miocene, to this fault, as the only rock which can be traced on both sides of the fault plane is Miocene limestone near Gugger's Hill, Ceres (Coulson 1930). However, if we consider the youngest rock in the low cliffs on the southern shore of Corio Bay to have been fractured by the fault, this is the Pleistocene limestone (Pritchard 1895) of Limeburner's Point, and in that case the fault occurred in late Pleistocene or sub-Recent times.

A note may be inserted here regarding the existence of a fault between Batesford and Fyansford, postulated by some authors. Between these two places the Newer Basalt occupies two distinct levels; on the eastern side of the Moorabool River it is at 200–250 foot altitude, while on the west it is at 100 foot altitude. To account for the lower level basalt, hinge faulting has been suggested (Fenner 1918), the let-down block lying between two faults. The East-West Barrabool fault and a hypothetical North-South fault running from Batesford to Fyansford. The latter " fault " does not exist, as was proved in 1926 by the bores put down by Australian Cement Ltd. to test the thickness of limestone in their new quarry at Batesford. It was discovered that the limestone throughout the area tested was undisturbed, whereas if a fault had traversed it there would have been a displacement of 150 feet. The difference of level in the basalt flows is due to the fact that they are separate flows (Coulson 1937), the lower one filling a stream-eroded valley.

4. *Moolap-Leopold trough fault.*

Stretching from north to south between Corio Bay and the Connewarre Lakes is a flat strip of country, scarcely 10 feet above sea level, bounded on the east by the Leopold-Kensington Hill, and on the west by the East Geelong Hill. It may be called the Moolap sunkland. Bores in the sunkland (Coulson 1935) reveal much the same sequence as in the bordering hills, though of course at nearly 100 feet lower level. The structure appears to be a genuine trough fault, the bordering hills representing the former fault scarps. The western fault extended from Limeburner's Point south to Torquay, and the eastern from Curlewis to Ocean Grove. The Newer Basalt has been displaced, so the fault would probably be late Pleistocene.

5. *Corio Bay-Port Phillip Bay-Bass Strait faults.*

The southern shore of Corio Bay has been proved to be the eastern extension of the Barrabool fault. The bay has a depth of about 30 feet in most parts, but becomes very shallow on the northern shore near Corio and Avalon. It is probable that there is no actual fault on the north side, and that the bay was formed by tilting towards the south. In this case, the short section of cliff at the extreme western end of the bay, between Western Beach and North Shore, must be a minor fault scarp, running north-south.

Corio Bay is, of course, only the western extension of Port Phillip Bay, the origin of which is attributed to faulting, with the maximum throw on the east side along Selwyn's fault. This paper is concerned only with that portion of the faulting which delimited the Bellarine Peninsula. Presumably there was a small fault along the coast from near Portarlington past St. Leonard's to Queenscliff and Point Lonsdale.

Little is known of the foundering of Bass Strait, but it is reasonable to suppose that the faults along the Victorian coast were parallel to the present shore line, and probably not far from it.

6. *Otway Ranges faults*

Recent field work by the author in the Otway Ranges has shown that over about 80 per cent. of the area, the Jurassic rocks dip to the south-east at about 15°. There are about half-a-dozen small areas, however, where this direction of dip does not hold. These are shown on the sketch map (Fig. 2). Unfortunately the field work is not yet advanced to the stage of plotting the numerous faults which have produced these tilted blocks in which the dip differs from the normal. There is no evidence of age available at present

FIG. 2.—Areas of abnormal dip in the Otway Ranges.

FOLDS.

1. *Waurn Ponds Monocline.*

A downwarp of about 60 feet to the north occurs in the Miocene limestone at Waurn Ponds, and runs E.N.E. for several miles until obscured by younger sediments, but probably extends across the hiatus of the Moolap sunkland to Curlewis, where there is a disturbed area. A flow of Newer Basalt from Mount Duneed crosses the monocline just west of the Waurn Ponds quarries (Quarter Sheet 28 N.E.) without notable diplacement, so possibly the monocline is a pre-basaltic feature.

2. *Curlewis contorted beds.*

The Tertiary beds at Curlewis beach and Clifton Springs have suffered from intense folding and minor faulting (Coulson 1933). The locality appears to lie at the intersection of several lines of weakness, viz., the Barrabool Hills-Curlewis fault, the Leopold-Kensington fault, and the extension of the Waurn Ponds monocline

3. *Torquay, Anglesea, and Airey's Inlet folds.*

Open folds occur in the Tertiary beds exposed in the coastal cliffs between Lorne and Ocean Grove, with anticlinal structures at Airey's Inlet, Anglesea and Torquay, and synclines between. A gentle synclinorium has thus developed, and its origin must be discussed. Hills (1935) considers that the folding is due to the differential uplift of the Otway Ranges (and consequent lateral pressure). In this case, the folding should be most intense near the Otways, but actually it is greatest at Torquay. The folding is to be attributed to sagging in the geosyncline of the Tertiary sea, for we know that the Tertiary beds form a tapered series, thin in the north and west, and thickest in the south-east, where differential subsidence must have occurred. This fo.ding would thus be contemporaneous with the deposition.

4. *Folding in the Otway Ranges.*

In the valley of the Wild Dog Creek about 6 miles from Apollo Bay there is exposed in a road cutting a small monocline in the Jurassic mudstones. It was originally noticed by V. Stirling (1901). At the extremity of Cape Otway, the Jurassic sandstones of the shore platform form a pitching anticline, the western leg dips north-west at 9 degrees, and the eastern dips north-east at 10 degrees. In the cliff just below the lighthouse there is a large fissure, which is apparently not connected with the anticline.

Both these structures appear to be local, and are probably due to sagging of competent beds. Usually in the Jurassics, earth-movements have resulted in faulting, but there are some small folds such as those described.

Upper Cainozoic Vulcanicity.

Starting in Upper Pliocene times and reaching a maximum in the Pleistocene, numerous volcanoes exuded the huge quantities of lava necessary to form the basalt plains of the Western District and Werribee fields. The petrological aspects have already been treated (Coulson 1937). Here we must consider the relation between the volcanic activity and the faulting, and the effect of the lava flows upon the drainage system.

It is the common phenomenon to find that the basalt boulders apparently clothe the face of the fault scarp, and Fenner (1918) has exhaustively discussed the three possible explanations, viz.:—

(*a*) the basalt flowed over a pre-existing fault scarp and solidified on the slope;

(*b*) the fault developed as the basalt was flowing or still plastic, the two being contemporaneous;

(*c*) the fault was later than the basalt, and displaced it, but the shattered basalt remained as partly buried blocks on the slope.

In the Geelong district the third of these processes seems to have been operative, and most of the faults are therefore late Pleistocene or Holocene.

After the major uplift which brought the Tertiaries above sea level, and before the eruptivity, a level plain stretched between the highlands of Ordovician rock in the north, and the Otway Ranges in the south. The original streams had begun to traverse this plain, the upper beds of which consisted of easily eroded Pliocene sands. Then came the floods of lava, filling the valleys and later forming a smooth field of lava with a gentle slope to the south. Bores through this basalt sheet have revealed the courses of the deep leads (Hunter 1909), and also show that the lava is much thicker along its northern margin (200 feet) than it is on the southern (about 30 feet). The general trend of the drainage was unaltered, although numerous small lava barriers interrupted the streams temporarily, especially in the case of the ancestral Moorabool.

Development of the Drainage System.

It is probable that the present drainage system is engrafted on that of pre-Tertiary times, at least in a general sense. The south-flowing streams from the northern highlands of the Divide, and the north-flowing streams from the Otways, originally discharged into the central arm of the Tertiary sea, which extended from Birregurra to Shelford and from Maude to Geelong. After the major uplift, these streams united on the Tertiary plains, and owing to the prevailing south-easterly dip of about 5 degrees that the Tertiaries have, the combined stream became a consequent river, the ancestral Barwon. Discharge was increased owing to the rejuvenation of the headwaters in the Divide and the Otways, and permanent valleys established.

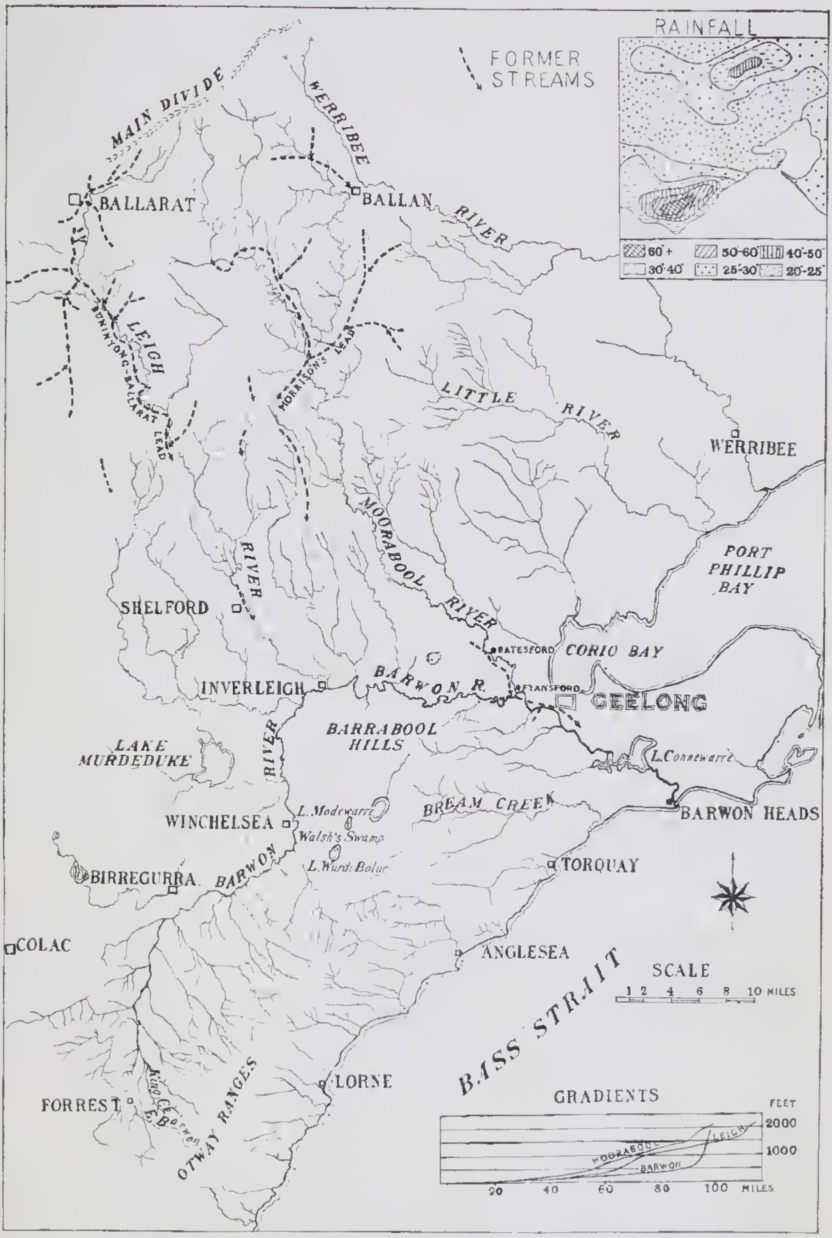

FIG. 3.—The Barwon-Leigh-Moorabool Drainage System.

The lava extrusions of the Newer Volcanic era did not materially affect the trend of these valleys, but led to entrenching and further rejuvenation. Relics of the basalt-filled valleys, shown in Fig. 3, occur at Durham Lead (Etheridge and Murray 1874), Shelford Lower Flow (Dennant and Mulder 1898), Morrison's Lead (Hunter 1909), She Oak Falls (Quarter Sheet 19, S.W. Note 2), and a hitherto undescribed flow extending from Batesford (Lower Flow) to Queen's Park, Fyansford, then through Newtown, Chilwell, South Geelong, Breakwater, and St. Alban's where it disappears beneath Recent sediments.

This flow fills a valley which was cut by the Moorabool River through the granite of the Dog Rocks, and extended south to Queen's Park where it junctioned with the Barwon at Buckley's Gorge. The former bank of this flow can be seen in Tertiary limestone exposed in a basalt quarry near Fyansford Bridge. The basalt-filled valley skirts the south side of Queen's Park at a high level, has been breached by the Barwon at Queen's Park Bridge, and crosses Newtown Hill to descend to Marnock Vale, where it received a small tributary from the direction of Highton, now seen as a residual on the east side of Prince's Bridge. This temporary barrier caused the formation of Harrison's Flats (terraced) on the west side of Prince's Bridge, and the accumulation of gravel and slate pebbles at Marnock Vale. There is no doubt that this stream was at one time the Barwon River, and it is important to remember its course when considering the former outlet of the river.

The present Barwon River rises from springs in the Otway Ranges near Mount Sabine, with tributaries starting at intervals along the north side of the main ridge towards Benwerrin. River capture has occurred where the former upper tract of the East Barwon is now occupied by the "big" King Creek (Gregory 1912).

Rich alluvial fans mark the debouchment of the Otway creeks on to the Tertiary plains. A bore at Barwon Downs showed 176 feet of sand and silt. Union of most of the tributaries is effected before Birregurra is reached; the river then proceeds to Winchelsea, where a right-angled turn takes it north to Inverleigh. Here it receives the Leigh River and reverts to its easterly course towards Geelong.

The right-angled turn of the Barwon at Winchelsea, was considered by Hall (1910) to be due to interference by basalt flows, from west of Winchelsea, with the original course of the Barwon, which, he said, coincided with that of the present Thompson's Creek (Bream Creek). This is a very tempting inference from the fact that a wide valley occurs between the Barrabool Hills and the Otway Ranges, partly filled with basalt,

and occupied by the insignificant Bream Creek. Closer examination reveals:—

(1) that the basalt did not come from "west of Winchelsea" but from a number of local vents, viz., a 550 ft. hill north of Wurdi Boluc, a 450 ft. hill near Winchelsea, Mt. Moriac, Mt. Duneed, and a hill near Pettavel, all rather local flows between which the river could easily have found its way;

(2) the Tertiaries between the valleys of the Barwon River and Bream Creek are the same height as the others of that locality, i.e., about 350 feet, and show no sign of a former deep valley having been filled with basalt;

(3) certain lakes in the valley, such as Lake Wurdi Boluc, Lake Modewarre, Walsh's Swamp, &c., which appeared to be remnants of a former large stream, have their beds partly in Tertiaries as well as basalt, and these beds are higher than the river level.

The supposed alteration of course is therefore not admitted, and the view is held that the Barwon always flowed to the west and north of the Barrabool Hills as it does at present, though possibly somewhat to the west of its present course.

Lake Murdeduke, west of the Barwon River between Winchelsea and Inverleigh, does not overflow to the Barwon, though some maps suggest that there is an outlet stream. A basalt ridge about 20 feet high separates the lake from the head of an intermittent creek which drains to the Barwon.

The Leigh and Moorabool Rivers commence as springs on the southern slopes of the Main Divide near Ballarat and Korweinguboora respectively and flow south, traversing Ordovician and Newer Basaltic rocks. Some waterfalls occur where the basalt flows have suffered headward erosion, e.g., at the Lal Lal Falls and the Moorabool Falls, or where lava barriers are encountered, as at the She Oak Falls.

Near Ballan the courses of the Eastern Moorabool and Werribee rivers approach very close, and Fenner (1918) considers that in pre-Newer Basaltic times both belonged to the Werribee system, the Eastern Moorabool later being captured by a stream which approached from the south.

A palpable error by Gregory (1912, p. 123) has left the widespread belief that the former mouth of the Barwon was in Corio Bay. The basalt which extends from Fyansford to Corio Bay was regarded by him as filling a former valley, but excellent cliff sections and road cuttings reveal that the basalt is part of a thin uniform sheet. From what has previously been said about the basalt-filled valley between Queen's Park (Fyansford) and Chilwell, it will be seen that the former Barwon always kept to the south side of the Newtown Hill, and entered the sea somewhere near its present mouth.

Conclusions.

1. The Otway Ranges constituted an island in the Tertiary sea.

2. Earth-movements of late Pleistocene age were responsible for most of the present topography.

3. The drainage system began in pre-Tertiary times, and engrafting took place after the post-Tertiary uplift.

4. The flows of Newer Basalt did not seriously interfere with the courses of the rivers. The Barwon did not flow along the valley of Bream Creek, nor was its mouth in Corio Bay.

Acknowledgments.

Thanks are due to the staff of the Geology Department, University of Melbourne; and to Messrs. G. B. Hope, W. Baragwanath, J. Easton, A. Mackie, J. B. Wilkie, and L. Coulson for assistance with the work.

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[Proc. Roy. Soc. Victoria, **51** (N.S.), Pt. I., 1938.]

Art. V.—*Petrology of the Tertiary Older Volcanic Rocks of Victoria.*

By A. B. EDWARDS, Ph.D., D.I.C.

[Read 9th June, 1938; issued separately, 23rd January, 1939.]

Contents.

Introduction.

The Old Volcanic Series:—
- Summary of Conclusions.
- Distribution and Field Occurrences.

Petrology.

Comparison with Other Tertiary Lavas in Victoria.

References.

Introduction.

The general division of the Tertiary lavas of Victoria into an Older Volcanic Series (Miocene or earlier) and a Newer Volcanic Series (Pliocene to Recent) was introduced by the early Geological Survey of Victoria. The conception was based on the relationships of the lavas in the Port Phillip district to fossiliferous marine beds, and was then extended by "conjecture or analogy" to lavas in other parts of Victoria. The evidence for correlation often appeared slender or doubtful, and there was little to indicate "whether the Older Basalts (Older Volcanic Series) were contemporaneous or part of a series of eruptions extending over a long period" (39).

The detailed study of these lavas has barely been begun, but a representative collection from most of the outcrops correlated with the Older Volcanic Series is now available. The collection comprises about 300 thin sections of lava flows and about 350 sections of dykes. The specimens from which these were made were gathered chiefly by officers of the Geological Survey of Victoria, but notable additions have been made by Messrs. W. McCance, A. Coulson, and R. Jacobson, and the author.

Petrological examination of this collection makes it possible to advance from the position outlined by Professor Skeats in 1910 (39, p. 201), and present a more comprehensive study of this igneous suite. Since the Newer Volcanic Series has also been studied in considerable detail (12), it is also possible to make a precise comparison of the Older Volcanic lavas with those of the Newer Volcanic Series.

The Older Volcanic Series.

Summary of Conclusions.

For convenience of presentation, the conclusions arrived at in the petrological section of this paper are summarized here. The Older Volcanic Series is a distinct petrological suite comprised

of crinanites, olivine-titanaugite-dolerites, olivine-titanaugite-basalts, olivine-basalts, olivine-nephelinites, limburgites, and monchiquites, camptonites, and possibly acid differentiates in the form of tinguaites and phonolites. This association is closely comparable with the late Palaeozoic igneous suite in the west of Scotland (51), and also with the Tertiary "plateau magma" suite of Scotland (25). The probable composition of the Older Volcanic parent magma is similar to the Scottish plateau magma type, and corresponds to Kennedy's "olivine-basalt magma type" (26). This must not be confused with the "plateau basalts" of Washington (52), which constitute the "tholeiitic magma type" (26) of Kennedy, or the "non-porphyritic central magma type" of Scotland (25). No tholeiitic rocks appear to occur in the Older Volcanic Series.

It has been found also that the Older Volcanic suite is distinct from the Newer Volcanic, both in the nature of many of its rocks and in the probable composition of its parent magma. While the Newer Volcanic parent magma is also an "olivine-basalt magma type," it has some pronouncedly tholeiitic features.

The presentation of these results is the more apposite in view of a recent publication by Sussmilch, in which he states (50, p. 26):—"The basalts of Victoria apparently belong to at least four distinct geological periods (*a*) Oligocene, (*b*) Lower Miocene, (*c*) Lower Pliocene, (*d*) Pleistocene to Recent. Under these circumstances the use of the terms Older and Newer Basalts (i.e. Volcanics) is misleading, and has led to much confusion, and it would be better if both terms were dropped."

In making this statement, Sussmilch has placed too much emphasis on the "distinctness" of these four periods. They represent a continuous passage of time. He has also overlooked two features of volcanic rocks, one of which is a tendency to intermittent eruption over a considerable period of time; the other, that rocks from a common stock possess common characters.

As is shown in subsequent pages, the Victorian basalts are divisible, on petrographic grounds, into two fairly well-defined and widespread suites. One of these suites includes lavas of a pre-Miocene to Miocene age. The other includes lavas of a Pliocene to Recent age—in other words, they correspond to an Older and a Newer Volcanic Series. This being so, the terms Older Volcanic Series and Newer Volcanic Series are neither misleading nor confusing, but express clearly and adequately the conception of two periods of volcanic activity.

It seems possible that these two eras of volcanic activity were only maxima in a single great period, the extensive Older Volcanic extrusions dying away during the Miocene to a few minor extrusions, and recurring in the Pliocene after a period of rest and renewed differentiation, as has been suggested by Skeats and

Summers (45, p. 53). These two periods of intense activity must themselves have been diversified by fluctuations in intensity, and shifting of the centres of extrusion.

Distribution and Field Occurrences.

The Older Volcanic Series includes both lava flows and dyke intrusions. These consist of practically identical rock types, but in different proportions, and the distribution is somewhat different.

Lava Flows.

The rocks constituting the lava flows are crinanites, titan-augite-dolerites and basalts, several varieties of olivine-basalt, and minor amounts of limburgites and nephelinite, and possibly acid alkaline rocks. Their age relations are well established in the Port Phillip district, where they occur beneath fossiliferous marine beds of Lower Miocene age, as at Flinders (27), Balcombe Bay, and Grice's Creek (38), Royal Park (37), Keilor (8), and in the vicinity of Geelong (7, and references), or intercalated between such beds, as at Maude (7).

In South Gippsland the basalts pre-date the Tertiary faulting, and lie beneath the main seams of brown coal. This has been proved by diamond drilling at Warragul, Yarragon, Morwell, Boolara, and Welshpool. Stirling (49) and Herman (17) have shown that the deposition of the brown coals occurred intermittently over a considerably longer period than was required for the extrusion of the basalts, so that there are pre-basaltic, inter-basaltic, and post-basaltic brown coals. Thus, in Bore No. 1, at Yarragon, the following intercalation of brown coal and basalt was found (49, p. 74) :—

	Thickness of seam or lava. Feet.
Brown coal	17
Brown coal	24
Brown coal	67
Brown coal	8
Basalt	41
Brown coal	1
Basalt	45
Basalt	18[illegible]
Basalt	70
Basalt	108
Brown coal	2

Similarly, at Leongatha, in Bores Nos. 3 and 5, seams of lignite, 6 inches and 9 inches thick, were found between basalt flows. The pre-basaltic and inter-basaltic brown coal seams are generally very thin, and never attain the great thickness of the post-basaltic brown coals. The most extensive development of brown coal beneath the basalts in South Gippsland is at Elizabeth Creek, in Allambee East, where there is a seam 40 feet thick while in the neighbourhood are seams 12 to 20 feet thick (49).

The brown coals of the Latrobe Valley are generally regarded as of Oligocene or Miocene age (38). Similar brown coals at

Parwan, Altona, Tyabb, Tanjil, and in East Gippsland underlie fossiliferous Oligocene or Miocene beds (4, 5), while at Hedley, near Gelliondale, brown coal is found beneath beds containing Pliocene fossils. On these grounds the basalts of South Gippsland should be Miocene or older. Sussmilch (50, p. 25) has claimed, however, that they "cannot be older than Lower Pliocene"; but in the same paper (50, p. 15) he arrives at the conclusions that the uppermost beds of the Yallournian (i.e. brown coal series) are possibly as young as Lower Pliocene, which would still make the basalts at least as old as Miocene.

At Dargo (33), Darlimurla (35), Narracan (3), Berwick (9), Pascoe Vale (34), Flemington (37), Beenak (24), Grice's Creek (38), Mahaikah (19), and Bacchus Marsh (32), the Older Volcanic basalts are found associated with Tertiary leaf beds. These leaves have been referred to the Miocene, but are not generally accepted as affording a precise indication of age. Nevertheless, the similarity of the leaf remains does suggest a broad contemporaneity for the lavas associated with them. At Berwick the leaf beds overlie a bed of brown coal from 2 to 3 feet thick.

The other lines of evidence as to the age of the Older Volcanic rocks, especially in East Gippsland, are the physiographic, which is described by Hills (18), and the petrological, given here. Correlation on petrological grounds tends to be regarded with suspicion, because rocks which originate by similar processes of differentiation must necessarily be generally similar in appearance and composition, even though formed at widely separated geological periods. It often happens, however, that a group of consanguineous rocks will possess minor peculiar characteristics which readily distinguish it from another generally similar suite. This is fortunately the case in Victoria, where both the Older Volcanic and the Newer Volcanic suites contain types with distinctive features and of widespread occurrence, viz., crinanites and titanaugite-basalts in the Older Volcanics, and iddingsite-basalts in the Newer Volcanics, as well as other less marked differences that are set out more fully in a later section (p. 92). Moreover, it has been found that classification of such rocks as Newer Volcanic or Older Volcanic by their petrological characters agrees closely with determination of their ages by physiographic or stratigraphic methods. The results of this classification by petrological characteristics, together with the data, are summarized in Fig. 1, which shows the probable distribution of the Older Volcanic lava flows in Victoria.

Dyke Intrusions.

The dyke swarms that accompany the Older Volcanic lava flows are comprised of crinanites, titanaugite-dolerites and basalts, olivine-basalts, monchiquites, rare nephelinites, and occasional camptonites, with possibly a few dykes of tinguaite and phonolite.

The age relations of these dykes are often obscure. At Kangaroo Gully, near Bendigo, they appear to be post-Permo Carboniferous (41). At Korkuperrimul Creek, Jacobson (20) has found several dykes of monchiquite and nephelinite which penetrate the earlier Older Volcanic flows, but either fail to penetrate the later ones or merge into them, so that there can be no doubt of their contemporaneity with the lavas. Equally definite relations can be observed in the neighbouring parishes of Gorong and Yaloak. Here the dykes in some instances penetrate the Older Volcanic basalts, but they clearly pre-date the Newer Volcanic basalts and the Tertiary leaf beds which the Newer Volcanic basalts overlie. These dykes are monchiquites, camptonites, and olivine-basalts, accompanied by a plug of olivine-nephelinite. Similar monchiquites and a nepheline-monchiquite occur further south at Anakies, and the You Yangs monadnock, and others presumably occur in the intervening country, beneath the Newer Volcanic basalts.

This swarm of dykes continues northwards, becoming dominantly monchiquitic with a minor number of camptonites, as far as Bendigo and probably Tarnagulla. Such dykes have been recorded from Steiglitz (15), Blackwood (14), Ballarat (16), Daylesford (53), Castlemaine (15), Maldon 15), and Bendigo (48).

No dykes occur in the Jurassic rocks of the Barrabool Hills or of the Otway Ranges, which are thus in striking contrast to the Jurassic hills in South Gippsland, where there is a strong swarm of crinanite, basalt, and monchiquite dykes. The western limit of the dyke swarm may be placed, therefore, between the You Yangs (and Curlewis) and the Barrabool Hills. A search through the literature reveals records only of diorite and acid lamprophyre dykes in the goldfields west of Ballarat, such as Beaufort, Scarsdale, Maryborough, Bealiba, St. Arnaud, Avoca, Stawell, and Wedderburn. The lamprophyres are in the main described as minettes, and seem to be contemporary with the diorites (i.e. probably Devonian), and so distinct from the Older Volcanic lamprophyres which are camptonites, sometimes grading into kersantites. An approximate western boundary of the Older Volcanic dyke swarm can be drawn from this data (Fig. 2).

In South Gippsland the dykes outcrop only in the upthrown blocks of the Jurassic, from which the Tertiary sands and brown coal have been stripped (10). They have been found in occasional diamond drill cores in the downthrown blocks beneath the Tertiary sands. They therefore pre-date the faulting of the region, like the lava flows, and since they are not recorded as penetrating the Older Volcanic flows, they are probably either earlier or contemporaneous with them. At Flinders, on the other hand, dykes occur in the basalts of the shore platforms.

In Eastern Gippsland there is no indication of the age relations other than that of petrological similarity. It is impossible to distinguish the crinanites, olivine-basalts, monchiquites, and camptonites that comprise the dykes of this region from those of the several areas previously referred to. A further line of evidence that supports the conclusion that all these dykes belong to the Older Volcanic Series is that the wide areas of Newer Volcanic rocks that have been examined seem to be practically destitute of dykes, despite many favorable exposures in stream sections.

As will be seen from Fig. 2, the Central Victorian dykes are dominantly monchiquitic with subordinate camptonites and basalts. Basalts become more prominent in the vicinity of Gorong, and are accompanied by occasional dykes of dolerite and nephelinite. East of Melbourne the basaltic dykes are increasingly predominant. In South Gippsland crinanites appear, and with olivine-basalts make up the majority of the dykes. The monchiquites are still numerous, and persist into Eastern Gippsland where they are joined by camptonites, phonolites, and tinguaites. The crinanites and olivine-basalts also persist into this region.

The full extent and strength of the Older Volcanic dyke swarms can only be conjectured. Heavy soils and vegetation obscure out-crops, and the dykes weather rapidly to considerable depths, so that generally they can only be observed in cuttings, stream sections, or mine workings. Mapping, moreover, has often been limited to rapid surveys.

The northern boundary of the swarm is equally a matter for conjecture. No Tertiary dykes are recorded in the north-east of the State, i.e., north and north-east of the Buffalo Mountains, Mount Hotham, and Glen Wills, although mapping in that part has been fairly detailed. Another hiatus occurs in North-west Gippsland. Tertiary dykes have been mapped in the Walhalla-Wood's Point belt (22, 28, 54), but none are recorded from further north. They have also been found at Warrandyte, Kangaroo Ground, and near Lilydale, but not further north. The mapping in this blank area has so far been of a reconnaisance character, so that dykes may well exist there. Still further north, however, where mapping has been more intensive, none have been observed, and since a number of dykes have been recorded in equally sketchily-mapped areas of Eastern Gippsland, they cannot be prominent in North-west Gippsland, and may not occur north of the tentative boundary suggested in Fig. 2.

Petrology.

The outcrops of Older Volcanic rocks about Port Phillip Bay, which undoubtedly underlie Miocene beds, were selected as the type Older Volcanics, particularly those of the Mornington Peninsula, which have the most extensive outcrop, and have been

explored by a number of diamond drill holes, the cores from which are available at the Mines Department. At Flinders one such bore was put down for more than 1,100 feet through a succession of basalt flows, while another at Cape Schanck penetrated about 800 feet of basalts.

The basalts in these areas contain abundant titanaugite and sometimes abundant analcite, combined with a relative absence of iddingsite, and are sometimes markedly ophitic in texture. They are distinct from the iddingsite-rich, titanaugite-poor basalts of the Newer Volcanic Series, but are identical with some of the dykes and volcanic necks of South Gippsland (10). These distinctive types are of wide-spread occurrence throughout Eastern and South-eastern Victoria, in association with other basalt types (Fig. 1), and serve as "marker flows" of a well defined petrological suite. Their presence among lavas of another area can be regarded as presumptive evidence that those lavas belong to the Older Volcanic Series, provided that there is no evidence to the contrary; and beginning with these types it has been possible to devise an approximate classification of the Older Volcanic Series into recognizable groups. In order to simplify subsequent discussion, local "type names," e.g., Keilor type, have been given to those groups which could not be given distinctive descriptive names.

Titanaugite Basalts.

Crinanites and Crinanite-basalts.

These doleritic olivine-analcite basalts occur in the lowermost flow of the Cape Schanck bore (700-850 feet), at Berwick (lower flow), at Kelly's Hill near Pakenham, at Gembrook, near Mardan, near Trafalgar, and at Narracan Creek (Allot. 125, Thorpdale), from Neerim to Noojee, at Leongatha, near Hallston, on the banks of the Latrobe River, north of Moe, and in diamond drill cores from the Dargo High Plains. They are coarsely ophitic rocks, and consist of a few embayed phenocrysts of olivine, which may be fresh or altered to serpentine, in a coarsely intergrown groundmass of plates of purple titanaugite up to 3 mm. across, and laths of labradorite (Ab_{35}-Ab_{40}) about 1.0-1.5 mm. long, coarse rods of ilmenite and needles of apatite, and interstitial analcite. The titanaugite sometimes encloses the olivine crystals. It is optically positive, with 2V about 60°, and pleochroic with X = purple-brown, Y = purple, and Z = yellow. Where it is in contact with analcite it may be altered to green aegirine-augite or even aegirine. The analcite is sometimes water-clear, but is more often cloudy and weakly birefringent. Flakes of biotite sometimes occur in association with the analcite and in cracks in the olivine. A finer-grained crinanite-basalt, showing flow arrangement in its groundmass, occurs at Warragul (Allot. 127).

These rocks cannot be differentiated from the crinanites which are so prominent among the north-west dykes of South Gippsland (10), and are probably co-genetic with them. No chemical analysis exists, but the composition must be closely similar to the analysis of the Gippsland crinanite shown in Table I., No. 1.

Ophitic-titanaugite-dolerites.

These differ from the crinanite-basalts only in the absence of analcite, and the minor amounts of aegirine and biotite. They occur at Korkuperrimul Creek, as the upper flow there (20), in the Dargo High Plain bore cores, at Upper Dargo, Cobungra, Mount Hotham, Mount Matlock, Yarragon, and on the Thomson River, and in the chilled base of the Neerim-Noojee crinanite, where it rests upon the Silurian. Similar rocks are found at Mallacoota and at Omeo as dykes.

Mooroodue Type.

A third group of closely comparable titanaugite-basalts occur in the Mooroodue bores (No. 8, 135-200 feet), Bittern bores (No. 2, 130 feet), Tyabb bore (No. 6, 404 feet), Flinders bore (No. 1, 0-99, 409, 536-671, 874-1135 feet), at Longwarry, in the Tangil bores at Bates Crossing (No. 4 and No. 7), Cape Schanck bore (No. 1, 43 feet), at Balnarring, Balcombe Bay, and San Remo, on the Bogong High Plains, in the bores from the Dargo High Plains, at Mother Johnson's Flat near Hotham, at Mahaikah, at Welshpool (bore No. 1, 440 feet), Toora (Allot. 15), at Berry's Creek, Mirboo (bore No. 20, 192 feet), in Devon (Allot. 103), at Maude, and at Russell's Bridge in the Geelong district, at the Korkuperrimul Creek, at Kangaroo Ground, Diamond Creek, and Greensborough, at Spring Plain, and Connor's Plain near Wood's Point, and at Flourbag Creek, Walhalla, at Livingstone Creek, and from a dyke in Collin's shaft near the junction of the Little Gibbo Creek with the Mitta Mitta. Similar dykes occur in South Gippsland (10).

These rocks are finer-grained than the previous groups. Olivine is the only mineral which forms phenocrysts. It may be fresh, corroded or, more frequently, altered to serpentine. The crystals range from 0.5 to 2.0 mm. in diameter, the smaller sizes being the more common. They are set in a medium-grained groundmass of violet titanaugite (2V about 60°), ophitic towards plagioclase laths (Ab_{40}), and abundant intersertal glass which is usually green, but sometimes yellow or brown. This glass is generally devitrified and birefringent, and is either chloritic or serpentinitic in composition (20). The degree of ophicity varies, as does the depth of colour of the titanaugite, and in chilled phases the pyroxene does not appear, but is replaced by an opaque glass which is packed with iron ore globules and is a purple or black colour. This glass resolves under high magnification into

a colourless base crowded with trichytes of iron ore. Such chilled phases are found at Tangil, Moorooduc, Flinders, and Tyabb.

A variant of this type is found at Korkuperrimul Creek, in the second lowermost flows of the Older Volcanic rocks of that district (20). The amount of green glass is diminished, and phenocrysts of titanaugite up to 3 mm. in diameter are present. The groundmass is coarser, and the unusually elongated laths of the plagioclase have segregated into sheaves. This feature is present to a lesser degree in a flow at Balnarring. An analysis of the Korkuperrimul rock is given in Table I., No. 4.

The specimens from Spring Hill and Connor's Plain, near Wood's Point, contain a greatly reduced amount of brown glass; and in specimens near Thomson's Bridge over the Latrobe (Narracan), and from half a mile east of Arthur's Seat, Dromana, and from Gembrook it is absent.

Iddingsite-Basalts.

Iddingsite-bearing basalts are relatively uncommon among the Older Volcanics, and such as do occur are readily distinguished from the Malmsbury and Footscray types of iddingsite-basalt so prevalent among the Newer Volcanics (12).

Iddingsite-titanaugite-basalts.

The basalt which occurs as a shore platform at Portarlington (7) is a typical titanaugite dolerite, except for the fact that the olivine crystals are heavily rimmed with red-brown iddingsite even when enclosed by titanaugite. Similar iddingsitization is observed in places in the olivine-titanaugite-dolerite which forms the uppermost flow at Korkuperrimul Creek (20).

The porphyritic variation of the Moorooduc type which occurs as the second lowermost flow at Korkuperrimul Creek, also grades locally into an iddingsite-titanaugite-basalt. The flows which overlie this rock are characterized by iddingsite (20), but this is accompanied by pale violet augite (2V about 60°) which is frequently pleochroic, and by varying amounts of clear green, yellow, or orange glass. The abundance of titanaugite in these rocks, and the type of glass mentioned in the last, readily distinguishes these rocks from the Newer Volcanic types of iddingsite-basalt.

Mirboo Type.

Iddingsite-basalts also occur in the Berry's Creek bore (No. 20) near Mirboo, where they form two flows, the uppermost (4th flow) and the flow at 117-147 feet depth (2nd flow); in the Flinders bore, as several flows (about 160 feet, 215 feet, 300 feet, 500 feet, and 850 feet levels); in the Cape Schanck bore; and at Evelyn.

These basalts are all fine-grained, slightly glassy rocks, consisting of phenocrysts of olivine slightly altered to iddingsite, set in a groundmass of plagioclase laths (Ab_{45}), granular to idiomorphic crystals of colourless or pale-violet pyroxene, iron-ore grains, and a variable amount of green glass. Numerous vesicles of chalcedony and glass are present in the Berry's Creek rocks, and in some slides a little biotite is present. The alteration of the olivine to iddingsite is of uniform extent, and pre-dates the crystallization of the pyroxene of the groundmass, since iddingsitized olivine crystals are frequently observed enclosed by aggregates of pyroxene. Small grains of iddingsite are present in the groundmass. The rock from the lower flow at Berry's Creek is a chilled phase, in which the felspar was unable to crystallize to any extent, so that it has the appearance of a limburgite.

The olivine cores may or may not be altered to serpentine. Such serpentine as is formed is often bright green, pleochroic to a yellow green. In the Flinders specimens the olivine crystals reach dimensions such as 3-4 mm. across, with a very thin rim of iddingsite, and in one of the higher flows at this locality the iron-ore forms coarse octahedra larger than the individual pyroxene grains.

In the Flinders rock from the 215-ft. core, the iddingsite is the yellow variety (36). It is strongly pleochroic and shows straight extinction. A vein of iron-oxide stained rock appears in the slide. As this vein is approached the yellow iddingsite makes over to red iddingsite. Chalcedony is again present as vesicles and veins.

The 4th flow at Barry's Creek has been analysed, and the analysis is shown in Table I., No. 9. The richness in magnesia is due to the presence of much serpentine, both pseudomorphous after the olivine, and as the green glassy base.

Olivine-basalts.

Associated with these more distinctive types of basalt are several other variations in which titanaugite is rare or absent.

Keilor Type.

A distinctive type of glassy olivine-basalt occurs at Green Gully, Keilor, below Lower Miocene marine beds (8), at Broadmeadows (47), along the Maribyrnong River at Essendon, at Cape Schanck (bore No. 1, 32 feet), at San Remo, and on Phillip Island.

It consists of microphenocrysts of slightly corroded fresh olivine, set in a groundmass of laths and microlites of plagioclase (Ab_{35}), minute grains of pyroxene, octahedra of iron ore, and abundant brown glass which constitutes over half the rock. The specimens from Essendon and Broadmeadows are identical except that an occasional phenocryst of (?) anorthoclase is present at the latter locality (47). The Cape Schanck and San Remo specimens

are rather more crystalline, so that the felspar laths are larger and the pyroxene grains larger and more numerous, while the amount of brown glass is less.

An analysis of the Broadmeadows flow is shown in Table I., No. 10.

Buckland Type.

An unusual type of basalt occurs as pipes and dykes in association with the phonolites and tinguaites of Harrietville. Rather similar rocks occur at Mt. Buffalo, Bogong High Plains, Sandy's Creek in the Tabberabbera district, and Cape Schanck. The dyke at Buckland Gap, near Harrietville, is selected as the type. It contains numerous phenocrysts of plagioclase, augite, and olivine, in a fine-textured groundmass. The plagioclase is labradorite (Ab_{45}), and frequently forms rectangular crystals. They are commonly corroded at the edge and at the core. The augite occurs as greyish-brown, idiomorphic crystals, sometimes 2-3 mm. in diameter. The cores of these crystals are sometimes pleochroic from pale green to yellowish-green. In other instances they are "spongy" with inclusions. Olivine crystals are smaller and less numerous, and are slightly altered to serpentine. The groundmass shows no fluxion structure, and consists of minute rectangular and lath-shaped crystals of labradorite, small grains of augite and olivine, and an interstitial base of minute grains of augite, iron ore, and glass. The other dykes and pipes of the district are similar, although the proportions of the phenocryst minerals vary.

In the rocks from Mt. Buffalo and the Bogong High Plains the proportion of plagioclase phenocrysts is greatly reduced, while the olivine and augite are more abundant, but often corroded. The augite has a marginal zone of titanaugite. At Sandy's Creek, on the other hand, phenocrysts of labradorite dominate. The Cape Schanck rock is closely comparable with Buckland Gap specimen, except that its pyroxene is a purple titanaugite. A somewhat comparable rock occurs at Grange Quarry, Double Creek, near Flinders, but here the phenocryts are solely of a brownish-violet augite, up to 2 mm. in diameter, and the fine-grained groundmass shows fluxion structure. No basalt of this type has yet been met with amongst the Newer Volcanic Series.

At Brandy Creek, near Mt. Bogong, a porphyritic type occurs in which idiomorphic phenocrysts of titanaugite, 10 mm. in diameter, are set in a medium-grained groundmass of corroded olivine, plagioclase laths, small crystals of violet augite, iron ore, and interstitial analcite, which shows weak birefringence.

Berwick Type.

Basalts of this group occur at Berwick, Bogong High Plains, Mt. Fainter, Mahaikah, Mt. Moreton (Belgrave), Korkuperrimul

Creek, Leongatha, Welshpool (Allot. 1 of B), Mt. Jim. and Battery Hill, Cobungra, and among the South Gippsland dykes. The type locality is the upper flow at Wilson's Quarry, Allotment 15 of Berwick.

It is a fine-grained olivine-basalt with microphenocrysts of olivine, more or less corroded, in a groundmass which shows little or no fluxion structure, and consists of olivine, pale violet to colourless augite granules, minute octahedra of iron ore, clear, colourless glass, and small but not very numerous laths of plagioclase (Ab_{35}). Between crossed nicols the rock has a characteristic appearance, small bright spots of olivine standing out in a black base which is flecked with minute, yellow spots (augite) and small grey laths of plagioclase. Rocks of this group are not easily distinguished from certain basalts of the Newer Volcanic Series.

At Berwick large phenocrysts of anorthoclase occur sporadically in the basalt. This feature is found in the Flinders type basalt at Aberfeldy (29), and also in a monchiquite-basalt at Moyarra (29).

Flinders Type.

This, the most widespread of the Older Volcanic basalts which does not carry titanaugite, occurs at Flinders (bore), Connor's Plain, Korkuperrimul Creek, Jindivick (Allot. 19), Grice's Creek, San Remo, Emerald, Mt. Hotham, Cape Schanck (bore), Royal Park, Alberton West (bore 92), Mooroodue (bore No. 9, 109-119 feet), Aberfeldy (Mt. Lookout and along the interfluve between the Thompson and the Jordan Rivers), Mt. Loch (Bogong High Plains), Ruby, Maude, Airey's Inlet, Curlewis, Sylvan, Leongatha, Warragul, Devon, Boolarra, Mt. Buller, Greensborough, Kangaroo Ground, Lilydale, South Buchan, White's Plain (Cobungra), 15 Mile Creek (Dargo), and among the dykes of South Gippsland (10).

Its characteristic feature is the presence of considerable amounts of green glass, generally devitrified, when it appears to be serpentine. It differs from rocks of the Mooroodue type in the absence of titanaugite and ophitic structure, but intermediate variations are to be found. Olivine is usually the only mineral occurring as phenocrysts. In some of the Flinders bore cores it forms crystals 2-3 mm. across, but it is generally smaller. The olivine crystals are nearly always corroded and partially altered to serpentine. Occasional microphenocrysts of brown augite and plagioclase accompany the olivine. Sometimes, as in one San Remo specimen, the plagioclase is more abundant. The groundmass frequently shows fluxion structure, and is an intergranular growth of pyroxene granules, laths of plagioclase (Ab_{40}), iron ore, and the intersertal green glass. The pyroxene varies from colourless to pale violet, when the rock grades into the Mooroodue type. The grain size is rather variable at different localities, and

in some instances the green glass is present in only small amount, or may be lacking entirely.

Rocks of this group are not readily distinguished from those of the Trentham type of Newer Volcanic basalt. Moreover, the distinction between the Berwick and Flinders type is based solely upon appearance in thin section. The two rocks are probably chemically similar, as is also the titanaugite-bearing Mooroodue type. Its difference from the Mirboo type is based on the absence of iddingsite, although the analyses (Table I., Nos. 5-8) suggest that the Mirboo type is rather more basic and richer in MgO.

Mugearites.

Mugearitic types are rare among the Older Volcanics, in contrast to their relatively widespread development among the Newer Volcanics. Only two occurrences are known—a pipe at Aberfeldy, described by Mahony (28) as an olivine-andesite, and a dyke on the Dargo High Plains. The felspar laths which constitute a large portion of the Aberfeldy rock are mostly oligoclase with cores of andesine. It undoubtedly belongs to this group, and should be called olivine-andesine basalt (or olivine oligoclase-basalt) rather than andesite. An analysis of the rock is given in Table I., No. 2, but there is some doubt as to whether the analysis quoted is really of this rock. Three analyses were made of the Aberfeldy basalts (Mem. Geol. Surv. Vict., No. 15, p. 44, Analyses 4, 7, 8). Of these, Analysis No. 4, reputed to be of the olivine-andesite, and Analysis No. 8, reputed to be a basalt, do not correspond with their respective thin sections. If, however, the analyses are interchanged, a very good agreement is found. It seems probable, therefore, that some mixing of the specimens has occurred. Accordingly, I have quoted Analysis 8 as representing the composition of the olivine-andesite.

Olivine-nephelinites, nepheline-limburgites and monchiquites.

Rocks of this character are known to occur at several places in the State, namely along Korkuperrimul Creek (20), at Greendale (42), at Drouin West (Allot. 91) (30), in the Bogong High Plains, and at the You Yangs(1). Only in the first of these occurrences is the age relation of the nephelinite beyond doubt. Jacobson (20, p. 134) has shown that at Korkuperrimul Creek there are several flows of olivine-nephelinite which grade laterally into nepheline-limburgites. They overlie flows of the Flinders and Mooroodue type, and are overlain by thin flows of limburgite and olivine-titanaugite-dolerite.

The Greendale occurrence is in the form of a plug intruding Permo Carboniferous glacial beds (42). Apart from its nepheline content, the plug resembles the Older Volcanic monchiquite dykes

of this district. The You Yangs occurrence is equally indefinite in age. It consists of a dyke with strongly monchiquitic affinities, accompanying monchiquite dykes which have invaded the You Yangs granite (1). It is probable that similar monchiquites intrude the surrounding Palaeozoic sediments, but are now hidden beneath the Newer Volcanic basalts.

The specimen from the Bogong High Plains is almost identical in appearance with that from the plug at Greendale, but is rather richer in nepheline. It was found by Mr. McCance, but was not in situ, so that its mode of occurrence is unknown. The other basaltic rocks of this area include definitely older Volcanic types.

The olivine-nephelinite at Drouin West, described by Mahony (30), is a plug surrounded by basaltic soil, so that its age is indefinite, although it appears to intrude the Older Volcanic lavas. This rock is a true nephelinite, and lacks the monchiquitic features of those from the other localities. It will be seen from the chemical analyses of Table II., Nos. 1-3, that the difference is expressed by the higher Na_2O content of the Drouin rock. The Korkuperrimul analysis is of a nepheline-poor variety of the type occurring there, and is therefore not truly representative of the soda-content of the olivine-nephelinites proper of that district.

Limburgites and Monchiquites.

Limburgites occur at a number of localities, but are not common as flows. The most extensive flows are in the Korkuperrimul Creek area (20), where they occur beneath basalts of the Flinders type, and above iddingsite-titanaugite basalts, and grade laterally into olivine-nephelinite. True flows or plugs occur at Euroa (? Newer Volcanic), Tommy's Hut, and Balwyn, and in the vicinity of Greendale. Other specimens in the collection are from Ensay, Broadford, the Basalt Temple on the Bogong High Plains, Mt. Hotham, Drumblemara (stone reserve), Mt. Deddick, Buchan (Allot. 10-18), the Buffalo Mountains (Crystal Brook), the Maude Mine at Glen Wills, the Blackwall Mine at Toombon, Harrietville (Rose, Thistle, and Shamrock Mine), Harkaway (N. of Berwick), and Parwan Creek (Yaloak). Most of these are from dykes, and they closely resemble the dykes of monchiquite in South Gippsland, Bendigo, Maldon, and Daylesford districts. In some instances they are clearly older than the Newer Volcanics, as at Yaloak and Greendale, but more often their relation is indefinite. However, it is to be noted that dykes appear to be rare among the Newer Volcanic lavas, although small flows are fairly numerous, as at Macedon, Woodend, Gisborne, Romsey, and Springfield (12). There is little, if anything, to distinguish between the limburgites of these two series petrologically.

Camptonites.

Dykes of camptonite are known to occur at Greendale, Daylesford, Bendigo (48), between Ensay and Jambarra, at Orr's Creek near Dargo, at Nedside on Livingstone Creek, and at Forest Hill, South Yarra.

The Greendale dyke intrudes the Ordovician in Dales Creek close to the plug of nephelinite, and is associated with dykes of monchiquite and olivine-basalt. It differs from the monchiquites in the presence of numerous microphenocrysts and wisps of brown hornblende and biotite, subordinate laths of plagioclase, and interstitial areas of felspar which may be anorthoclase. In this respect it is similar to the Bendigo camptonites. Some of the titanaugite crystals have cores of emerald green pyroxene which is pleochroic to yellow green, and appears to be aegirine. It differs from the biotite-lamprophyre at the freehold Mine, Daylesford, only by the absence of coarse crystals of biotite.

Slides of a similar rock from a locality called Ferntree Gully on the track from Ensay to Jambarra, were found in the Howitt Collection (in the Melbourne University). In these, however, the hornblende is restricted to numerous laths and wisps in the groundmass, and is accompanied by more aboundant biotite. Allied dykes in Orr's Creek and Livingstone Creek contain abundant crystals of brown hornblende and biotite. In the section from Livingstone Creek the hornblende crystals are frequently as large as 3 mm. in diameter, and are accompanied by titanaugite crystals of the same dimensions. The titanaugites, like those in the Greendale rocks, have cores pleochroic from deep green to greenish-yellow. No plagioclase occurs in these latter two specimens, however, so that they represent an intermediate stage between the camptonite proper and the monchiquites. The gradation from the other end, by the development of "ocellar" patches of sub-radiate hornblende laths and analcitic glass, has been noted in the dykes of monchiquite at Bendigo (48) and South Gippsland (10).

Acid Differentiates.

There has developed a tendency to regard all the Tertiary alkaline rocks in Victoria as belonging to a single Middle Kainozoic Alkaline Series, distinct from both the Older Volcanic and the Newer Volcanic Series (e.g. 50, p. 25). This is, however, a misunderstanding of the facts, which appears to have grown from a statement made by Professor Skeats in 1910, when referring to the difference in age between the Macedon dacites and the Macedon alkali rocks, namely: "The Alkali Series is a much younger one, of probably Mid-Kainozoic age, since the later rocks merge into the newer basalts" (Newer Volcanics) (39, p. 203). In the same paper he suggested that the similar alkali rocks in the Western District "may be of the same age as the Macedon

rocks" (p. 204), while in 1912 (45, p. 53) and 1914 (40), it was further suggested that a number of the isolated occurrences of phonolite, tinguaite, and solvsbergite might also be of the same age as the Macedon rocks.

It is unlikely, however, that all the Tertiary alkaline rocks in Victoria were extruded simultaneously, and in some localities there is proof that they were not. Petrogenetic studies of the Newer Volcanic Series in Central Victoria (12) have made it clear that the solvsbergites, trachytes, trachyphonolites, and trachyandesites of Macedon, Trentham, Tylden, Bullarto, Coliban, and Gisborne, are the typical acid-differentiation products of the olivine-basalt lavas with which they are associated, and the same seems to be true for the trachytes of the Western District. Such associations are characteristic of olivine-basalt provinces throughout the world (46), and are to be expected wherever conditions have permitted more or less complete "cupola differentiation" to take place (11, 13). The time most favorable to complete differentiation is generally that immediately preceding the beginning of extrusion. Subsequently the main magma reservoir is thought generally to have approached so close to the surface that further extrusion occurs before there is time for repeated advanced differentiation. Thus it is that the greatest development of alkaline types in olivine-basalt provinces throughout the world has been during the early stages of extrusion (46). The Newer Volcanic lavas of Victoria are no exception in this respect.

As indicated above, the alkaline lavas are pictured as centred above cupola-like protrusions of the main magma reservoir. Although in each locality in which they occur they will be among the early extrusions from that cupola, it is unlikely that all the cupolas of a province will develop at the same time and rate, so that there will be no definite period of alkaline extrusions. Moreover, if extrusion is interrupted for a sufficiently long period, renewal of differentiation within the magma reservoir may give rise to later alkaline rocks, as it has done at Coleraine and Casterton (40), and at Gisborne.

A feature of the Tertiary alkaline rocks of Victoria is that those which definitely belong to the Newer Volcanic period are predominantly trachytes or have trachytic affinities, while those which outcrop in Eastern Victoria, in proximity to the Older Volcanic lavas, are predominantly phonolitic or have affinities with phonolites. This may be a coincidence, but it assumes significance in view of the richness of the Older Volcanics in soda, expressed by the development of olivine-nephelinites, analcite-basalts, and crinanites, as contrasted with the relative richness of the Newer Volcanics in potash, as indicated by the

development of macedonites, mugearites, and woodendite. This raises the possibility that the isolated occurrences of alkaline rocks in Eastern Victoria may, at least in part, be acid differentiates of the Older Volcanic Series.

The alkaline rocks most likely to belong to the Older Volcanic Series are the pipes and dykes of phonolite, sodalite-phonolite, and tinguaite near Harrietville (42), which occur in association with pipes and dykes of olivine-basalt of the Buckland type. These pipes are from 50 feet in diameter, up to 20 acres in extent. The rocks composing some of them differ from the alkaline rocks in other parts of Victoria in that they contain numerous phenocrysts of basaltic hornblende which is reacting with the groundmass to form aegirine and iron ore. In a number of instances the brown basaltic hornblende, which shows straight extinction, remains only as a core to a deep green hornblende with an extinction angle of 20°. The alteration is transitional, so that there can be little doubt as to the sodic character of the green hornblende. This development of basaltic hornblende in phonolites, with subsequent alteration to aegirine, appears to be a characteristic feature of many phonolites and allied alkaline lavas. Its restriction to strongly differentiated types has led the author to suggest that it forms during the cupola stage of differentiation of a basaltic magma (13).

Other acid alkaline types which may belong to the Older or Newer Volcanic Series are a dyke of phonolite from Dargo flat (Howitt Coll.) (43), the phonolite and tinguaite dykes of Tabberabbera (44), the phonolites, tinguaites, trachytes, and solvsbergites of Omeo (40), the biotite-phonolite of Gallows Hill, near Mahaikah, in the Mansfield district (40), and possibly the trachyte-solvsbergite dykes and syenite of Mt. Leinster (2). This is, of course, purely conjecture, particularly since Newer Volcanic lavas occur in the region, as at Benambra and Gelantipy (18).

Pyroxenes.

No very definite statement can be made as to the composition of the pyroxenes. Approximate measurements of 2V were made (by comparison of acute bisectrix figures with such figures for minerals of known 2V; muscovite and aragonite) wherever possible. These gave values of 2V about 60° for the titanaugites, but in the basalts without titanaugite the pyroxene grains were generally too small for determination. Such measurements as were achieved gave values of 2V of about 50–60°, and such pyroxenes were presumed to be diopsidic. No pigeonites were observed.

Chemical Compositions.

Analyses of the Older Volcanic rocks are not as numerous as could be desired. The chemical compositions of the dyke rocks in South Gippsland and Bendigo have been given elsewhere (10, 48). In the two tables that follow (Tables I. and II.), all the existing analyses of Older Volcanic basalts other than these are set out. They are too few for well-defined groups to show out, but suggest that the differences between the Mooroduc, Flinders, Mirboo, and Keilor types are petrographical rather than chemical. This probably applies to the Berwick type also.

Table I.

——	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SiO_2	47·70	45·29	51·31	46·64	47·89	46·04	45·64	46·43	44·91	44·95
Al_2O_3	17·76	19·83	18·03	15·46	16·16	15·08	14·35	17·60	13·77	15·50
Fe_2O_3	2·23	4·90	1·50	4·49	2·00	5·08	2·08	8·51	5·28	2·04
FeO	8·25	6·43	7·32	7·25	8·88	6·95	10·32	2·44	5·81	10·47
MgO	6·50	2·49	5·60	7·24	6·23	7·02	9·50	8·03	12·19	7·43
CaO	9·37	9·80	8·74	10·80	10·39	7·75	7·87	8·12	8·56	8·24
Na_2O	3·34	4·24	3·30	2·43	3·37	3·76	2·17	3·56	1·73	3·04
K_2O	1·59	1·96	2·26	0·92	1·47	2·41	1·23	0·92	0·94	1·98
H_2O +	0·85	1·02	0·79	1·83	1·34	1·20	1·92	1·20	3·40	2·60
H_2O −	0·27	0·38	..	0·89	0·15	0·57	1·29	0·81	1·34	0·52
CO_2	tr.	nil	0·88	tr.	nil	nil	0·47	nil	tr.	0·18
TiO_2	1·02	2·35	tr.	1·90	1·75	2·78	2·74	2·25	1·73	2·77
P_2O_5	0·51	0·62	0·45	0·32	0·78	1·44	0·42	0·37	0·32	0·52
MnO	0·24	0·23	tr.	0·04	0·19	0·28	0·13	0·22	0·33	0·21
Li_2O	..	..	..	..	..	..	..	..	tr.	..
Ci	0·03	tr.	..	..	tr.	tr.	0·02	..	nil	..
S	0·02	nil	..	..	tr.	tr.	0·14	..	nil	..
BaO	0·03	..	..	..	..	..	nil	..	..	..
Total	99·69	99·45	100·18	100·21	100·60	100·36	100·40	100·53	100·39	100·45

(1) Corrected for Cl, S

(7) Cr_2O_3 ·01, V_2O_5 ·05, SrO ·02, ZrO_2 ·03, NiO ·07

(9) NiO ·03, CoO tr., Cr_2O_3 ·05

1. Crinanite dyke (not rich in analcite), creek west of Gibson's allotment, Kilcunda. Analyst—A. B. Edwards (*Proc. Roy. Soc. Vic.*, 47, 1, p. 123, 1934).
2. Mugearite pipe, Binn's Creek, Aberfeldy. Analyst—W. L. Robertson (Mem. Geol. Surv. Vic., 15, p. 45, 1925). (See note p. 85.)
3. Tachylyte, Tanjil. Analyst—A. W. Howitt (Vic. Nat., 2, p. 67, 1885).
4. Mooroodue type, porphyritic variety, Korkuperrimul Creek Analyst—R. Jacobson (*Proc. Roy. Soc. Vic.*, 50, 1, 1937).
5. Flinders type, Mt. Lookout, Aberfeldy. Analyst—M. K. Evans (Mem. Geol. Surv. Vic. 15, p. 45, 1925).
6. Flinders type, Mt. Lookout, Aberfeldy. Analyst—M. K. Evans (Mem. Geol. Surv. Vic., 15, p. 45, 1925).
7. Flinders type, railway cutting, Royal Park, Melbourne. Analyst—W. McCance (*Proc. Roy. Soc. Vic.* 44, 2, 1932).
8. Flinders type, fine-grained flow, Greensborough. Analyst—N. R. Junner (*Proc. Roy. Soc. Vic.*, 25, 2, p. 335, 1913).
9. Mirboo type, Berry's Creek Bore, No. 20, depth 90 feet, allot. 34, Mardan. Analyst—A. G. Hall (Ann. Rept. Sec. Mines, 1911, p. 62).
10. Keilor type, Quarry, section xv., Tullamarine (Broadmeadows). Analyst—F. L. Stillwell (*Proc. Roy. Soc. Vic.*, 24, 2, 1912).

TABLE II.

—	1.	2.	3.	4.	5.	6.
SiO_2	41·13	42·39	39·79	44·67	44·56	45·56
Al_2O_3	15·74	16·17	12·11	12·39	11·68	13·32
Fe_2O_3	4·02	4·29	4·67	3·96	3·95	2·30
FeO	7·71	5·79	7·87	7·53	6·88	9·68
MgO	7·98	7·66	12·25	9·67	11·91	11·12
CaO	10·48	11·57	11·29	10·16	10·37	8·77
Na2O	5·56	4·26	2·83	1·84	1·03	3·02
K_2O	1·12	1·46	1·23	1·85	2·31	1·53
H_2O + ...	2·11	1·85	1·79	3·92	2·97	1·28
H_2O −	0·58	0·56	3·06	0·92	0·84	0·27
CO_2	nil	nil	nil	tr.	nil	nil
TiO_2	2·34	2·13	1·87	2·52	2·90	3·00
P_2O_5	0·54	1·16	1·30	0·14	0·40	0·71
MnO	0·14	0·23	0·02	tr.	0·24	0·19
Li_2O	tr.	..	..	..	tr.	nil
SO_3	nil	..	..	0·15	..	nil
S	..	0·13	..	0·47	0·06	..
Cl	nil	0·11	..	tr.	tr.	0·05
BaO	..	0·01	..	..	..	..
NiO, CoO	..	nil	..	..	0·01	0·01
Cr_2O_3	..	0·03	..	..	0·09	0·06
V_2O_3	..	0·01	..	..	..	..
TOTAL ..	99·45	99·70	100·08	100·19	100·20	100·87

1. Olivine-nephelinite, Allotment 91, Parish of Drouin West, plug. Analyst—F. F. Field (*Proc. Roy. Soc. Vic.*, xliii., 2, p. 128, 1930).
2. Olivine-nephelinite, plug 8 chains S. of Greendale Hotel, Parish of Blackwood. Analyst—A. B. Edwards (*Proc. Roy. Soc. Vic.*, xlvii., 1, p. 123, 1934).
3. Olivine-nephelinite, lava flow (limburgitic phase), 50 yards from the head of a small gully on the western slopes of Bald Hill, Bacchus Marsh. Analyst—R. Jacobson (*Proc. Roy. Soc. Vic.*, 50, 1, p. 145, 1937).
4. Limburgite, dyke, Blackwall Mine, Aberfeldy. Analyst—M. K. Evans (Mem. Geol. Surv. Victoria, No. 15, p. 44).
5. Limburgite, small flow, Euroa. Analyst—A. G. Hall (Ann. Rept. Sec. for Mines, for year 1912, p. 62).
6. Limburgite plug at Balwyn. Analyst—P. W. G. Bayley (*Proc. Roy. Soc. Vic.*, xxiv., n.s. 1, p. 133, 1911).

If analyses 1, 2, and 3 of Table I., and all of Table II. are excepted as differentiated types, then the average of the remainder (Table I., Nos. 4-10) which are the widespread, little differentiated types, gives a composition which may be regarded as approximating to the composition of the "parent magma" of the suite. This shown in Table III. below:—

TABLE III.

—	Older Volcanic Magma type.	Newer Volcanic Magma type.	Olivine-basalt Magma type.	Tholeiite Magma type.
SiO_2	46	50	45	50
Al_2O_3	15·5	15	15	13
FeO, Fe_2O_3	11·5	11·5	13	13
MgO	8	8·5	8	5
CaO	8·8	8·5	9	10
Na_2O	2·9	3·0	2·5	2·8
K_2O	1·4	1·2	0·5	1·2

From this it seems probable that the parent magma of the Older Volcanic Series approximates to the "olivine-basalt magma type" (26), and is also fairly comparable with the parent magma of the Newer Volcanic Series. This, however, as indicated by its SiO_2 content, is more nearly intermediate between the olivine-basalt magma type and the tholeiitc magma type. The Older Volcanics show little resemblance to the tholeiites.

Comparison with Other Tertiary Lavas in Victoria.

It remains to compare the Older Volcanic Series with the other Tertiary igneous rocks of Victoria.

Newer Volcanic Series.

There is a general similarity between the Newer and the Older Volcanic Series in that both are olivine-basalt associations, and gave rise to alkaline end-products. There are, however, some outstanding differences:—

1. Existing analyses indicate that the basalts of the Older Volcanic Series approach more closely to the olivine-basalt magma type in composition than those of the Newer Volcanic Series, which have tholeiitic tendencies.

2. The dominant basalts of the Newer Volcanic Series (Malmsbury and Footscray types) are characterised by an abundance of iddingsite and a paucity of titanaugite (12). On the other hand, titanaugite is the common pyroxene of many Older Volcanic basalts, while iddingsite is of only local occurrence.

3. Crinanites are unknown among the Newer Volcanics, but are widespread among the Older Volcanics.

4. Such Newer Volcanic basalts as do not contain iddingsite are generally associated with more completely differentiated types, such as mugearites, trachyandesites, and trachytes.

5. Mugearites are prominently developed among the Newer Volcanics, but are rare among the Older Volcanic rocks. This finds further expression in the fact that the differentiated Newer Volcanic types are rich both in soda and potash, while the comparable rocks among the Older Volcanics are rich in soda.

6. Basic alkaline types are only weakly developed among the Newer Volcanics, where some limburgites contain analcite. Among the Older Volcanics, however, olivine-nephelinites are of relatively frequent occurrence.

7. Dykes are uncommon among the Newer Volcanics, but are prevalent among the Older Volcanic rocks.

8. The Newer Volcanic basalts are relatively fine-grained, and generally have intergranular textures. The Malmsbury and Footscray types are greyish in colour when fresh, and often vesicular, while the Trentham type and mugearites are bluish-green when fresh. The titanaugite members of the Older Volcanic basalts, on the other hand, generally possess ophitic textures, and are frequently relatively coarse-grained. Older Volcanic basalts are rarely vesicular, and are generally dark coloured, so that they possess a distinctive appearance even in the hand specimen.

There can be little doubt, therefore, as to the difference between these two suites of Tertiary lavas. It cannot, of course, be claimed that the petrological examination of any specimen is sufficient to assign it to one or other suite, but for a number of rock types this is so, and fortunately these types occur in a number of areas.

Suggested Intermediate Series.

Jutson (23) has suggested that on physiographic grounds the basalts at Ivanhoe and Greensborough, and possibly those at Kangaroo Grounds, are of Pliocene age, and intermediate between the Older and Newer Volcanics. The Greensborough and Kangaroo Ground basalts have been described by Junner (21). The basalts at both localities include ophitic olivine-titanaugite dolerites, identical with those of the Older Volcanic Series, and an identical type occurs as a small residual at Diamond Creek in the same district. In view of the uncertain nature of Jutson's evidence, it seems probable to the author that these residuals are Older Volcanic and not Pliocene.

Other Gippsland Localities.

The lavas in the Gelantipy area, and those in the neighbourhood of Benambra, shown as Newer Volcanic on the 8 miles to an inch map of Victoria of 1902, and as Older Volcanic on the 16 inch maps of 1909 and 1936, appear on petrological evidence to be Newer Volcanic. Iddingsite basalts of the Malmsbury-Footscray group are found at both localities, together with less distinctive types. This agrees with the physiographic evidence (18).

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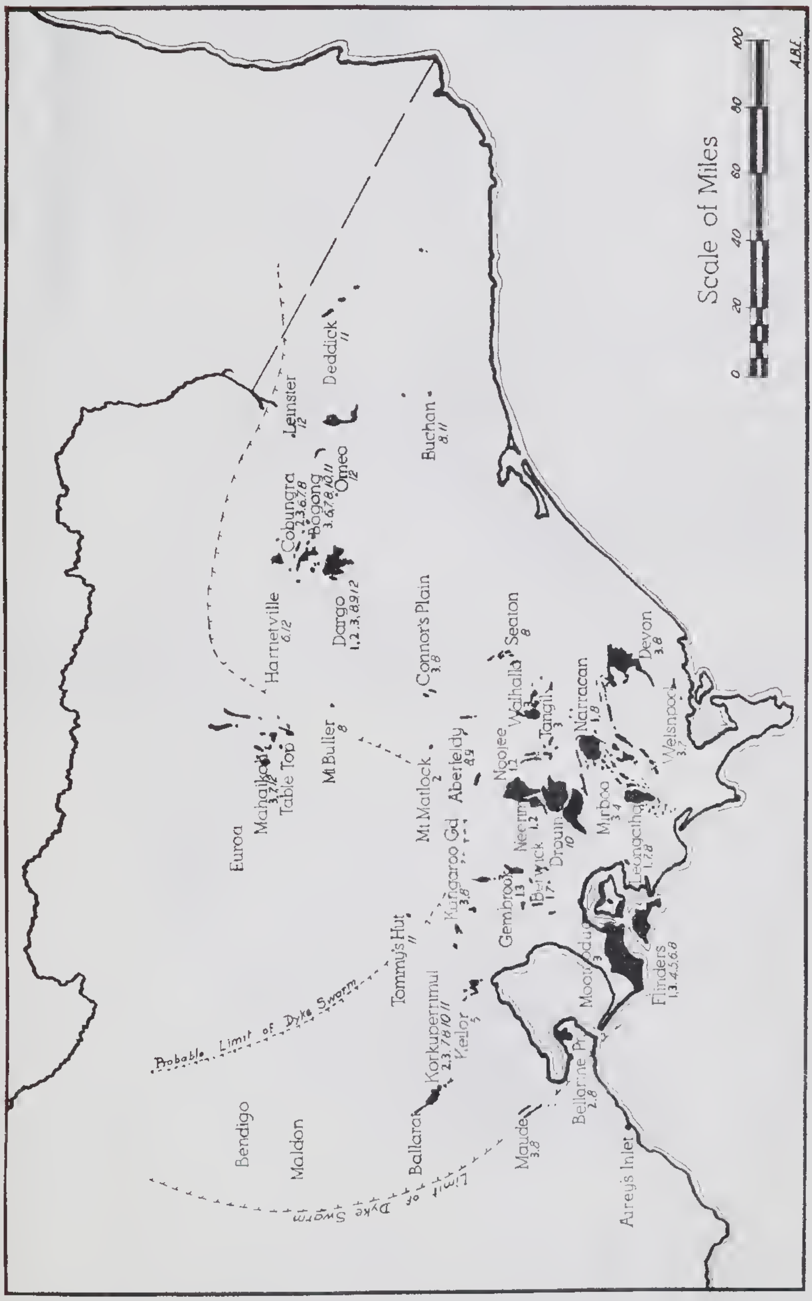
List of Illustrations.

Text-fig. 1.—The Probable Distribution of the Tertiary Older Volcanic Lavas in Victoria. *Marker Types*:—**1**. Crinanites and crinanite-basalts; **2**. Titanaugite-dolerites; **3**. Mooroodue Type. *Other Types*:—*4*. Mirboo Type; *5*. Keilor Type; *6*. Buckland Type; *7*. Berwick Type; *8*. Flinders Type; *9*. Mugearites; *10*. Olivine-nephelinites; *11*. Limburgites; *12*. Acid Alkaline Types.

Text-fig. 2.—The Probable Distribution of the Tertiary Older Volcanic Dykes in Victoria.



Scale of Miles
0 20 40 60 80 100
A.B.E.
Deddick 11
Leinster 12
Cobungra 2,3,6,7,8
Bogong 3,6,7,8,10,11
Omeo 12
Buchan 8,11
Harrietville 6,12
Dargo 1,2,3,8,9,12
Connor's Plain 3,8
Seaton 8
Walhalla
Tanjil 3
Narracan 1,8
Devon 3,8
Welshpool 3,7
Table Top
Mt Buller 8
Mt Matlock 2
Aberfeldy 8,9
Noojee 12
Neerim 1,2
Drouin 10
Mirboo 3,4
Leongatha 1,7,8
Berwick 1,7
Gembrook 13
Kangaroo Gd 3,8
Euroa
Tommy's Hut 11
Probable Limit of Dyke Swarm
Korkuperrimul 2,3,7,8,10,11
Keilor 5
Flinders 1,3,4,5,6,8
Bellarine Pt 2,8
Maude 3,8
Bendigo
Maldon
Ballarat
Aireys Inlet
Limit of Dyke Swarm

Fig. 1.

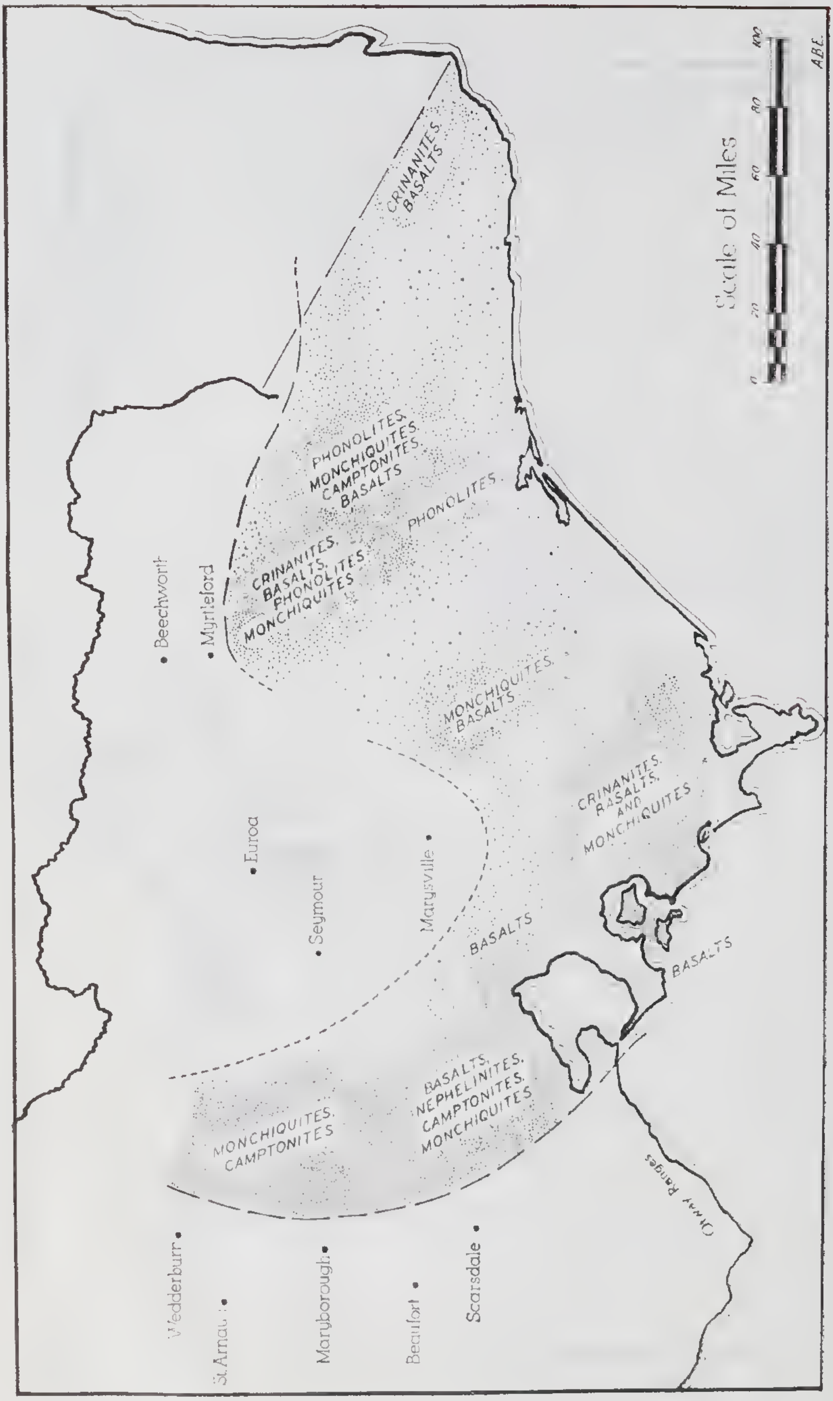

CRINANITES.
BASALTS
PHONOLITES.
MONCHIQUITES.
CAMPTONITES.
BASALTS
PHONOLITES.
CRINANITES.
BASALTS.
PHONOLITES
MONCHIQUITES
MONCHIQUITES.
BASALTS
CRINANITES.
BASALTS.
AND
MONCHIQUITES
BASALTS
BASALTS
BASALTS.
NEPHELINITES.
CAMPTONITES.
MONCHIQUITES
MONCHIQUITES.
CAMPTONITES
Beechworth
Myrtleford
Euroa
Seymour
Marysville
Wedderburn
Maryborough
Beaufort
Scarsdale
Otway Ranges
Scale of Miles
0 20 40 60 80 100
ABE.

Fig. 2.

[PROC. ROY. SOC. VICTORIA, **51** (N.S.), PT. I., 1938.]

ART. VI.—*Two Gregarines from Ctenolepisma Longicaudata with Notes on Forms in other Silverfish.*

By EDER LINDSAY, B.Agr.Sc.

[Read 14th July, 1938; issued separately, 23rd January, 1939.]

During the study of the feeding habits of the silverfish *Ctenolepisma longicaudata* Esch. it was found that these insects were frequently infected with gregarines. This silverfish has not been studied previously, but gregarines have been found in related genera. Watson-Kamm recorded one gregarine from *Lepisma saccharina, Gregarina lagenoides* Labbé, but did not mention the two gregarines which J. W. Cornwall, 1915, had found in the same species. More recently J. A. Adams, 1935, described two new forms from *Thermobia domestica,* namely *Lepismatophila thermobiae.* and *Colepismatophila watsonae,* for which he created the two new genera.

Two new gregarines were found in the mid-intestines of *Ctenolepisma longicaudata,* and these have been named *Lepismatophila ctenolepismae,* sp. nov. and *Gregarina ctenolepismae,* sp. nov. The former is a large form which was easily seen during the dissections, but the latter was noticed only when the insects were examined under the binocular ($\times$ 70).

Most of the insects were collected in Melbourne, but the wide distribution of the parasites was evident from the infested insects collected in Toowoomba and Brisbane, Queensland; Bigga, N.S.W.; Renmark, S.A.; Launceston, Tasmania; and Boyup Brook, W.A.

Materials and Methods.

As the trophozoites live in the mid-intestine, the alimentary canals posterior to the crop were dissected out, slit longitudinally, and the contents examined in water. Fixed preparations were also made following the methods of MacKinnon and Ray 1933. The alimentary canals were immersed in Carnoy's fluid for twelve hours. Some were then stained twenty minutes in Ehrlich's haematoxylin and finally dissected in clove oil. Others were cut into sections 5-7μ thick, longitudinally and transversely, and stained three minutes in Ehrlich's haematoxylin. This stain differentiated clearly the different parts of the protoplasm of the gregarines. The trophozoites were more difficult to fix than the tissues of the gut, and in several sections the larger ones tended to break.

The cyst wall was impervious to stains and no attempt was made to follow the nuclear changes associated with the development of the cyst, but at various stages during the ripening the contents of the cysts were examined after fixing with Carnoy, breaking the wall, and staining with haematoxylin or saffranin.

In the dissected insects the trophozoites of both forms were found attached to the epithelium of the crypts in the sacculi and anterior part of the mid-intestine. Here they caused the atrophy of the neighbouring cells, but apparently no other damage, even where the infestation was so heavy that the parasites occupied the greater part of the gut. The infestations of both forms were usually heavy, frequently 20 or 30 individuals of both gregarines occurring in a single insect. Generally these were of various sizes, and observations extending over two years showed that the gregarines had no seasonal cycle so that the silverfish were always liable to be infested.

Lepismatophila ctenolepismae sp. nov.

This form was found in about 80 per cent. of the silverfish examined.

Trophozoite.—The earliest stages of the life cycle are presumably passed inside the epithelial cells, but the smallest trophozoites found were already extracellular. In one case a minute form was located, shown in Fig. 3, which may be a young trophozite. The body of the smallest form which could be recognized with certainty was cylindrical though not divided, and had a large spherical epimerite embedded between the epithelial cells. Observations at later stages showed that the septum between the protomerite and deutomerite then develops, and the front end becomes broader and broader, until the whole trophozoite becomes roughly "turnip-shaped" (Figs. 4 and 5). Later the more mature trophozoite rounds off with the protomerite remaining as a capping at one end. It was of interest to notice that the "tail" region gradually merged into the body of the trophozoite without leaving the sucker-like scar referred to by MacKinnon and Ray, 1931, in *Selenidium.*

The protoplasms of the three divisions of the young trophozoite appear different in transmitted light and stain differently with Ehrlich's haematoxylin. That of the deutomerite is the most densely granular particularly around the nucleus. That of the protomerite, though less dense, shows a coarse structure when fixed and stains more deeply than the deutomerite. This same coarse structure appears, however, in the deutomerites of many of the more mature trophozoites (Fig. 2, *l.c.*), and frequently tiny granules which stained deeply with haematoxylin were found imbedded in the protoplasm. The protoplasm of the epimerite is densely granular and when fixed shows a fine structure.

The nucleus is 25–40μ in diameter in about the centre of the wide part of the deutomerite. By exerting gentle pressure it can be moved about the body. When stained it shows one caryosome.

The body is bounded by the pellicle which is thin in the region of the epimerite and protomerite but forms a thick refractive coat to the deutomerite and, in the tail region, is thrown into three or four transverse ridges. In the transverse section the "tail" shows as a lightly granular disc surrounded by more deeply stained material enclosed by the thick pellicle (Fig. 2*a*). The mature trophozoites break free of the intestinal walls, usually with the epimerites still attached. These latter become less granular as the gregarines move down the intestine, and finally disappear from the trophozoites. Detached epimerites were never found.

Some of the free trophozoites still remain pressed close to the walls below the sacculi, fitting into small depressions where the epithelial cells have atrophied (Fig. 2). The mature trophozoites pass down the mid-intestine in groups of 20 or 30 lying between the intestinal wall and the peritrophic membrane (Fig. 19, Plate VI.). No temporary associations are made in the group, but when the trophozoites reach the posterior end of the mid-intestine association occurs, protomerite to protomerite, usually between only one or two pairs at a time. These sporonts secrete a white cyst wall, and pass into the hind intestine. Unassociated sporonts did not pass into the hind intestine as had been noticed by Cornwall.

Cyst.—The shining white cysts are conspicuous in the faecal material, usually one being attached to each pellet. They are of two distinct forms, round and oval. As both these forms gave rise to the same kind of spores they were considered to belong to the same species of gregarine. Of 25 cysts measured, the average size of the spherical cysts was $252\mu \times 238\mu$ and of the larger oval cysts $316\mu \times 466\mu$ (standard deviation of 14μ).

The cysts were freed of faecal matter and kept under both moist and dry conditions at 23°C. so that the development could be followed. The cysts from fresh faeces usually contain two sporonts although development sometimes proceeded further inside the intestine. Development proceeds under dry conditions or in water. The cyst wall darkens, becoming first a mottled grey, then black as the cyst ripens. The sporonts divide into many gametes, each about 13μ diameter, but no sexual differentiation could be seen. Then hundreds of tiny spores, almost transparent, separate around the granular residual protoplasm which forms into many non-nucleated masses, which become more definite, though they still can be readily plasmolysed. These and the large oil globules in the cyst gradually disappear as the spores ripen. The spores have a large central nucleus and thick transparent walls which gradually become thicker and darker. At the same time the cyst wall becomes darker, and

the pitted and grooved dark outer layer can be separated from the colourless inner layer (Fig. 8). The cyst finally ripens in about fourteen days.

The ripe cyst is black and dented, and through the semi-transparent wall the dark spores can be seen crowded towards one end. The ripe spores are black, semi-transparent, flattened ovals with one side more curved than the other, 15 to 17μ long, 4 to 6μ wide, and 4μ thick. Each has a large globule at its centre with smaller globules at the end and along the more curved side (Fig. 9). The spores tend to hold together end to end (Fig. 10) and when liberated by the rupture of the cyst come out in many long spring-like chains, extending in some cases for about 8 mms. around the cyst.

The spores contaminate the food and so reach the insects' intestine again. Many spores were found in the crops examined. Some were broken across the middle and some at one end; but no spores split longitudinally as described by Cornwall. Broken spores were also found in the hind intestine but no spores were noticed in the act of germination. The spores could not be broken by pressure and stains would not penetrate the thick capsule so that the sporozoites could not be distinguished. But the heavy infestations would suggest that each spore contains several sporozoites. (Cornwall found 8 sporozoites.)

TABLE 1.—MEASUREMENTS OF TROPHOZOITES OF LEPISMATOPHILA CTENOLEPISMAE (MICRONS).

Total Length.	Protomerite.		Deutomerite.		Epimerite Width.
	Length.	Width.	Length.	Width.	
429	352	168	76	153	..
400	..	..	..	184	..
386	306	177	79	165	..
341	262	81	..	..	37
283	..	171	..	153	..

GREGARINA CTENOLEPISMAE sp. nov.

This smaller gregarine was found in about half the silverfish dissected.

Trophozoite.—The trophoziote is heart shaped, about as long as wide, and attached to the wall by a peg-like epimerite set in the depression at the top of the "heart." The body is not divided into protomerite and deutomerite. The nucleus (6–9μ diameter) is at the base of the depression, and seems to be attached to the pellicle (cf. Chakravarty, 1935). In the living gregarine it is hidden by the densely granular protoplasm. When fixed, the protoplasm shows a finer structure than in the previous form. Around the nucleus it stains deeply with haematoxylin, and deeply stained strands radiate from the nuclear area. The pellicle is thin.

The smallest form recognized measured $5\mu \times 7.3\mu$ (Fig. 13), but most of the gregarines were larger than this (Table 2). The gregarines occur singly or in pairs, the outer one, the satellite, fitting over the primite still attached to the wall (Figs. 11 and 12). There seems to be no other record of syzygy occurring while the gregarines are still attached to the walls (Wenyon 1926, p. 1146, and Henry 1932). Usually both members are the same size, or the satellite is a little larger. During dissection the larger pairs readily come free of the wall with the epimerite still attached. They frequently separate from each other and roll over so that the epimerite is hidden in the depression at the top.

Usually only a few free pairs of trophozoites and associating sporonts are found in the lower part of the mid-intestine, instead of the large group of unassociated trophozoites found in the *L. ctenolepismae* infestation. It is not certain that the same pair remained associated until mature, for by the time the sporonts had encysted they were no longer fitting over each other but were in the position indicated in Fig. 14.

Cyst.—The small shining white cysts containing the two sporonts pass out with the faeces, usually three or four adhering to each pellet. At first the wall is thin (3μ), but thickens to about 6μ and finally to 10μ as the sporonts fuse and the cyst ripens. It stains deeply with haematoxylin. In three days eight to nine spore ducts protrude through the cyst wall from the protoplasmic mass inside. These grow out about 10μ from the cyst (Figs. 15 and 16). In six days at 23°C. the tiny white

TABLE 2.—MEASUREMENTS OF GREGARINA CTENOLEPISMAE (MICRONS).

Unassociated Trophozoites.	
Width.	Length.
18·0	18·0
34·0	31·6
73·4	65·5
78·6	78·6
78·6	76·0
92·0	82·0
94·3	91·8
99·8	94·3
145·0	141·0
161·0	122·0

Trophozoites in Syzygy.		Young Cysts.	
Width.	Total Length of Pair.	Width.	Length.
microns	microns	microns	microns
84	145	69	69
107	153	107	95
153	184	84	69
230	260	100	107
..	..	84	84

refractive spores exude in chains from the ducts like fine white filaments extending about 1.4 mm. around the cyst (Fig. 17). The regular oval spores measure $3.2\mu \times 2.2\mu$. The small amount of residual protoplasm consists mainly of globules about half the size of the spores.

The cyst matures in the dry faeces. If kept in water the young cysts plasmolyse, and the older cysts swell till about 125μ diameter.

Feeding Experiments.

An attempt was made to follow the development of the gregarines in the intestine of the silverfish. The insects were supplied with clean food until cysts were no longer found in the fresh faeces. They were then fed for two days with food artificially infected with ripe spores of both gregarines, and then removed to clean food which was changed daily. Subsequent dissections and sections revealed trophozoites of various ages in the mid-intestine and many spores in the crop, but no germinating spores or very small trophozoites. The insects were held at 23°C. throughout.

To find the duration of the trophozoite stage a group of naturally infested insects were fed on clean food and the faeces examined daily for cysts. Dissection of several insects, during these observations revealed the presence of trophozoites in the mid-intestine. After 26 days, however, no more trophozoites of *Gregarina ctenolepismae* were present and cysts were no longer found in the faeces. Further, on the 35th day no cysts of *Lepismatophila ctenolepismae* were found, and dissection of the remaining thirteen insects showed that only one harboured mature trophozoites. Since sporonts and cysts were never found to collect in the hind part of the intestine it is concluded that these periods give a lower limit to the duration of the trophozoite stage.

To facilitate the examination of the mid-intestine the infected food was stained with Sudan III, which is taken up by the epithelial cells. The trophozoites of *Gregarina ctenolepismae* take up a little of the red and appear pink surrounded by the red epithelial cells. The trophozoites of *Lepismatophila ctenolepismae* remain uncoloured.

Systematic Position.

In general characteristics the two gregarines described resemble somewhat those found by Cornwall and Adams, but detailed examination showed several differences. For example, *Lepismatophila ctenolepismae*, sp. nov. resembles *Lepismatophila thermobiae* but the spores have not the regular oval shape described by Adams, one side being more convex than the other.

It also resembles Cornwall's form A, but the spore walls are smooth instead of pitted. *Gregarina ctenolepismae*, sp. nov. resembles Cornwall's form B, but the epimerite is peg-like rather than acicular as figured by Cornwall.

Following the classification of Watson-Kamm (1922) both gregarines are placed in the family Gregarinidae; the larger form as a new species of Adams' genus *Lepismatophila*, *Lepismatophila ctenolepismae*, and the small form as a new species of *Gregarina* (Dufour), *Gregarina ctenolepismae*.

Diagnosis.

Lepismatophila ctenolepismae sp. nov.

No syzygy in sporonts. Trophozoite septate, conoid, 390μ $\times$ 164μ. Epimerite smooth, globular. Cyst round 245μ diameter; or oval, 315μ $\times$ 460. dehisce by rupture. Cyst wall black, pitted and grooved. Spores in uncoiling chains. Spores black, ellipsoidal, one side more convex than the other, 16μ $\times$ 5μ $\times$ 4μ. Spore wall smooth.

Gregarina ctenolepismae sp. nov.

Syzygy in cephalonts and sporonts. Trophozoites heart shaped 87μ wide $\times$ 80μ long, non-septate. Epimerite simple peg shape. Cyst white, smooth-walled, spherical 85μ diameter. Spores liberated in chains through spore ducts. Spores oval 3.2μ $\times$ 2.2μ. Spores white smooth walled.

Gregarines in other Silverfish.

The intestines of other species of silverfish were examined for gregarines. *Lepisma saccharina*, the common pest of the Northern Hemisphere is found only occasionally in Australia. Of the six so far examined, three harboured a trophozoite, (Fig. 18) different from the gregarines so far recorded for the *Lepismatidae*. *Ctenolepisma lineata* var *pilifera* is another form collected occasionally with the common silverfish. Three individuals were examined, and in one were found several trophozoites resembling *Lepismatophila ctenolepismae* Luc. These insects had been kept for a time in captivity and several cysts were found in the faeces which had collected. These were small and round and contained the typical spores of this same gregarine. Somewhat similar trophozoites were found in two preserved specimens of *Thermobia aegyptica* Luc. A few native silverfish have been examined, one *Acrotelsella*, and one *Heterolepisma*, collected with the common silverfish, two from termites nests, and two from under bark, but none have contained gregarines.

It is interesting to note that the three species collected together in houses have not the same parasites though they have the same feeding habits and presumably would have the same chances of infection. *Lepismatophila ctenolepismae* occurs only in *Ctenolepisma longicaudata,* and *Ctenolipisma lineata* var *pilifera* which have sacculi in the mid-intestine and not in *Lepisma saccharina* where these are absent. Sufficient material of *Thermobia aegyptica* was not available to permit any conclusion regarding the identity of the gregarines found, and further examination is necessary before any importance can be attached to the absence of gregarines in the native forms.

Summary.

Two new gregarines have been found in the silverfish *Ctenolepisma longicaudata* Esch—which have been named *Lepismatophila ctenolepismae* and *Gregarina ctenolepismae.* These have been described and their life cycle followed. Further, to determine the specificity of the gregarines, several other species of silverfish have been examined. *Lepismatophila ctenolepismae* sp. nov. was found only in *Ctenolepisma lineata* var. *pilifera* Luc. A different form was found in *Lepisma saccharina* (Fig 18) and two unidentified forms in *Thermobia aegyptica* Luc.

Acknowledgment.

The author wishes to thank Miss J. Raff for her guidance and Professor S. M. Wadham for many suggestions; also Mr. Ogilvie for the microphotographs and Dr. Turner for advice regarding the naming of the species.

Explanation of Figures.

Fig. 1. Longitudinal section of the anterior portion of the mid-intestine showing trophozoite stage of the two gregarines, l.c. *Lepismatophila ctenolepismae,* and g.c. *Gregarina ctenolepismae,* in the epithelial lining of the sacculi. Portions *a* and *b* show the sacculi not cut in true section, *f* folds in epithelium below the sacculi, *crp.* crypts, *v.* villi. × 38.

Fig. 2.—Tangential longitudinal section of the lower mid-intestine, showing a group of mature trophozoites. *l.c. L. ctenolepismae, a* section of "tail" region, *d.pr.* sporonts with dense protoplasm, *g.c. G. ctenolepismae.* × 38.

LEPISMATOPHILA CTENOLEPISMAE.—Figs. 3-10.

Fig. 3.—A form found in the sections which may be a young trophozoite $9\mu \times 2\mu$. × 250.

Fig. 4.—Young trophozoite showing epimerite, drawn from two successive sections. × 250.

Fig. 5.—Outlines of both free and attached forms of trophozoites drawn from living material to show the variation in shape. × 100.

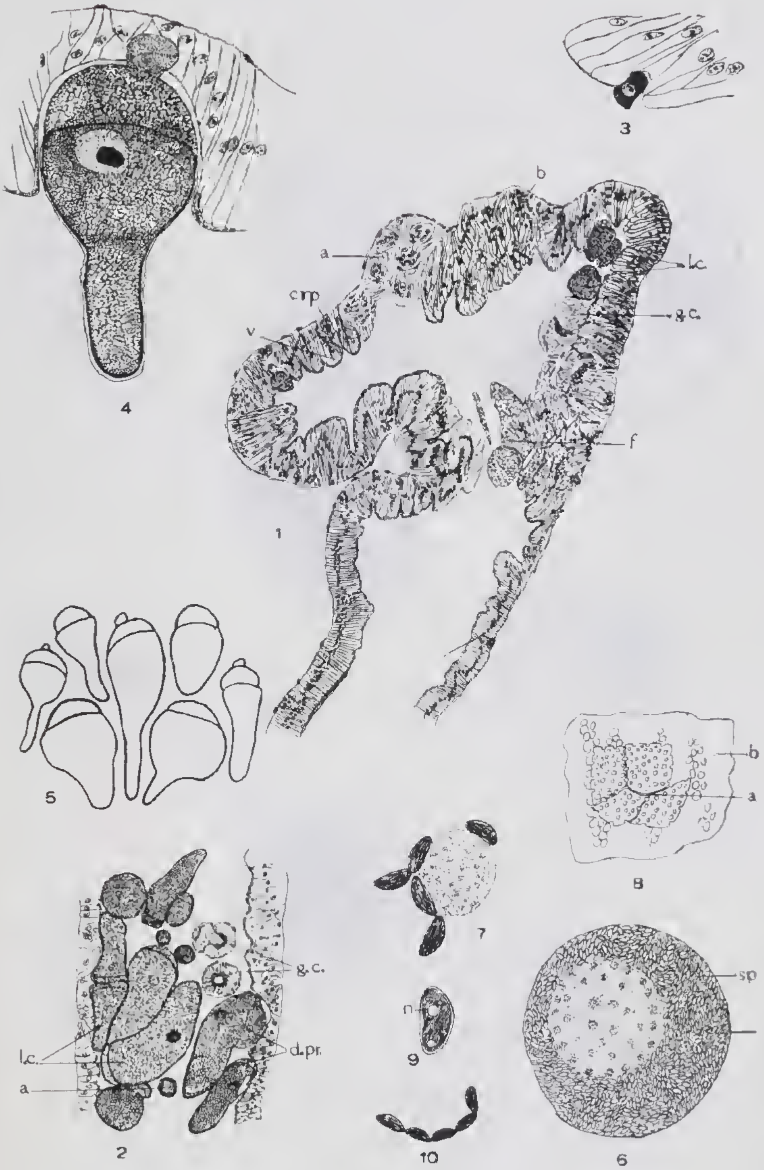
Fig. 6. Optical section of developing cyst. The transparent spores have separated around the central mass of protoplasm. × 60.

Fig. 7.—Young spores and spherical mass of protoplasm from a fractured cyst. × 300.

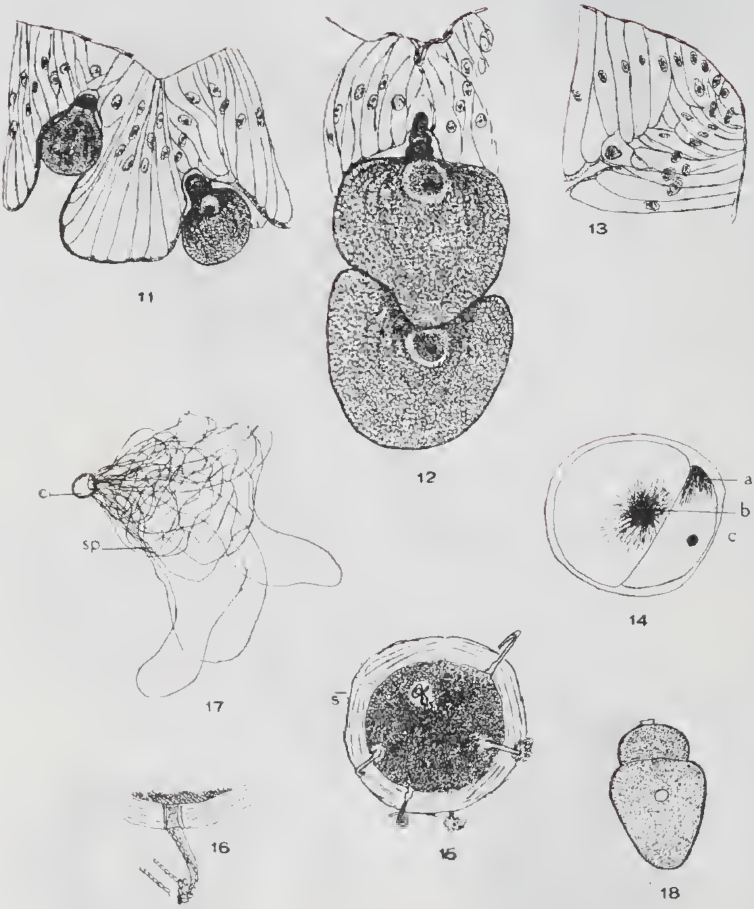
Fig. 8.—Cyst wall with pits and grooves.
a. Groove in outer black layer of wall.
b. Inner colourless layer marked by circular areas. × 340.

Fig. 9. Optical section of ripe spore, showing the nucleus *n* and other globules. × 310.

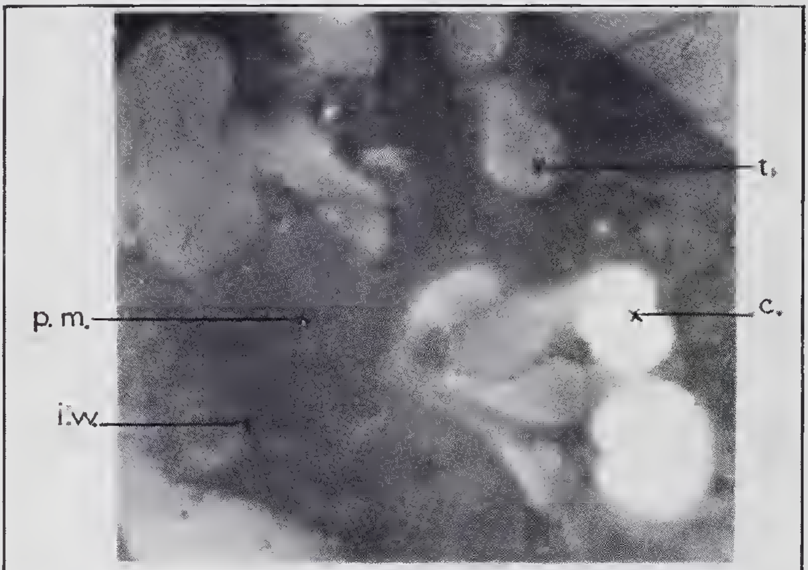
Fig. 10. Chain of ripe spores. × 330.



Text Figs. 1–10.



Text Figs. 11–20.



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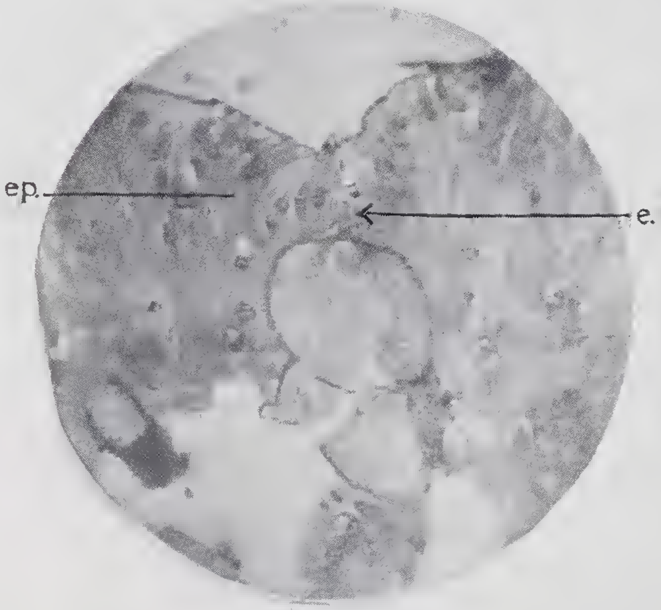

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GREGARINA CTENOLEPISMAE—Figs. 11-17.

Fig. 11.—Trophozoites. × 250.

Fig. 12.—Large trophozoites in syzygy drawn from 3 sections. × 250.

Fig. 13.—A small gregarine intracellular $4.9\mu \times 7.3\mu$ (× 250).

Fig. 14.—Optical section of a newly formed cyst enclosing the associated sporonts. Stained with Ehrlich's haematoxylin.

a. Heavily stained area of second sporont. × 340.

b. Heavily stained protoplasm surrounding the nucleus.

c. Nucleus of second sporont.

Fig. 15.—Cyst showing spore ducts. × 340.

Fig. 16.—Spore duct of cyst with chain of spores exuding through duct. × 400.

Fig. 17.—Ripe cyst *c.* with chains of spores *sp.* exuded. × 15.

Fig. 18.—Unidentified trophozoite from *Lepisma saccharina.* × 180.

PLATE VI.

Fig. 19.—Microphotograph lower part of mid-intestine opened to show trophozoites *t.* and cysts *c.* of *Lepismatophila ctenolepismae* lying between the intestinal wall *i.w.* and the food enclosed in the peritrophic membrane *p.m.* × 480.

Fig. 20.—Microphotograph of large trophozoites of *Gregarina ctenolepismae* in syzygy, attached to the epithelium *e.p.* by the epimerite *e.* × 230.

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[Proc. Roy. Soc. Victoria, **51** (N.S.), Pt. I. 1938.]

Art. VII.—*The Age and Physiographic Relationships of the Cainozoic Volcanic Rocks of Victoria.*

By EDWIN SHERBON HILLS, Ph.D.

[Read 14th July, 1938; issued separately, 23rd January, 1939.]

I. Introduction.

It has always been realized that the determination of the geological ages of the various Cainozoic lavas that occur in this State is a difficult task, and that, as Skeats has remarked, one's conclusions must frequently be based "only on conjecture or analogy." Nevertheless, by correlating stratigraphical, petrological and physiographical data collected over a long period, certain generalisations have been arrived at concerning these rocks, which have been widely, though not universally, accepted. Thus it has come to be believed that there were two main periods of eruptive activity during the Cainozoic Era, during which an Older Volcanic Series, of Oligocene to Lower Miocene age, and a Newer Volcanic Series, of Pliocene to Recent age, were developed (Smyth, 1858; Skeats, 1910; Singleton, 1935). Furthermore, maps published after 1902, on which the Older and Newer Volcanics are differentiated, show all the Cainozoic lavas east of the meridian of Melbourne as Older Volcanics, Newer Volcanics being restricted to the region west of the meridian of Melbourne. This view was tentatively accepted by Skeats (1910) in the absence of definite evidence that would indicate the presence of Newer Volcanics in eastern Victoria, and I also adopted it in discussing the physiography of the Eastern Highlands (1935). Recent work, however, indicates that this generalisation is unsound, and evidence for the presence of Newer Volcanic rocks in the Eastern Highlands will be presented in the first section of this paper.

The Newer Volcanic Series is currently regarded as dominantly Pleistocene with a few Pliocene and Recent members (Singleton, 1935, p. 134; Jutson and Coulson 1937), but Walcott (1920, p. 83) has suggested that the upper flows at Pitfield Plains, which are typical Newer Volcanics as far as their field occurrence is concerned, may be Miocene in age, and that there may have been no well marked break in volcanic activity between the extrusion of the Older and Newer Volcanic Series. Sussmilch (1937) has gone further, and grouped most of the Newer and Older Volcanics, so distinguished by Victorian geologists, together as Lower Pliocene, and David (1932, Table I.) regarded the main period of extrusion of the Newer Series as Upper Pliocene. In

early official publications by members of the Geological Survey (summarised in Murray's *Victoria: Geology and Physiography*, 1895) the Newer Volcanic Series was also stated to be Pliocene, but in a recent pamphlet (Prospector's Guide, 3rd Edn., 1936) these rocks are classed as Pliocene to Recent.

In view of the conflict of opinion regarding the age relationships of the Older and Newer Volcanics, I propose to discuss in the second section of this paper the evidence adduced by previous authors concerning the age of these rocks, together with such new stratigraphical and physiographical evidence as I have been able to obtain. Edwards (1938) has recently discussed the petrology of the Older Volcanic lavas, and data from this aspect will be dealt with only incidentally in the following account.

II. The Cainozoic Lavas of Eastern Victoria.

In view of the wide acceptance of the generalisation concerning the non-existence of Newer Volcanics in this district, which is given official recognition in the latest geological map of the State published by the Mines Department (1936), and also in an earlier edition (1908), it is interesting to note that on the larger scale, 1902 map (1 inch=8 miles), several patches of Newer Volcanic rocks are marked in the Eastern Highlands. In the legend of this map, however, one such patch (Gelantipy) is classed as Older Volcanic, suggesting that this and the other patches may have been coloured as Newer Volcanic owing to an oversight. On the other hand, Dunn, who was Director of the Survey when the map was prepared, has referred in print (1914) to one such patch, a few miles south of Euroa, mentioning the occurrence of scoria cones, ash beds, and vesicular and dense lavas which he compared with the typical Newer Volcanics of Western Victoria. It may be, therefore, that the colouring was given to these occurrences intentionally, but, if so, no reason for the subsequent change in the 1908 map, on which they are shown as Older Volcanics, is known to me, and there are indications in the older literature that the view expressed on the 1902 map may have had some foundation in the beliefs of the geologists of the last century.

It is clear, for instance, that it was at first only McCoy's comparison (1878) of the sub-basaltic leaf remains on the Dargo and Bogong High Plains with the Miocene flora of Europe that caused the Survey to class these and other Cainozoic lavas in the Eastern and South Gippsland Highlands as Older Volcanics, for Howitt (1879) stated that he believed all the North Gippsland occurrences, including those of the High Plains, Morass Creek, Gelantipy, and South Buchan, to be Newer Volcanics. Owing to McCoy's work and the partial elucidation of the stratigraphy of South Gippsland, the High Plains occurrences and those of Aberfeldy, the South Gippsland Highlands, Berwick, &c., were

subsequently classed as Older Volcanics, but since no published statement as to the existence of stratigraphical or physiographical evidence of the age of many of the smaller patches of lava in the Eastern Highlands had been made, I conclude that later reference to these as Older Volcanics (e.g. Dunn (1907) and Murray (1908) on Morass Creek, and the Geological Survey in the 1908 and 1936 maps) are based " only on conjecture or analogy."

Direct stratigraphical evidence that would serve to define precisely the ages of these patches is, indeed, lacking, and one is necessarily forced to rely on physiographical analogies with occurrences whose age can be determined from stratigraphical data. South Central Victoria and South Gippsland afford excellent standards by which to judge the age of the lavas of the Eastern Highlands, for their geology and physiography are known in considerable detail, and they afford examples of lavas of diverse age and physiographical setting. They will therefore be used as key areas in the following discussion.

Older Volcanics in South Central Victoria and South Gippsland.

Although Sussmilch has argued that the so-called Older Volcanic lavas of Berwick, Tanjil, Aberfeldy, Narracan, and Morwell are of Lower Pliocene age, all Victorian workers are agreed that they are either Oligocene or Lower Miocene. The latter belief is founded in part upon the direct stratigraphical evidence that the lavas are interbedded with the base of the main lignite series, which is regarded (Singleton, 1935, p. 128) as either of the same age or slightly older than Lower Miocene or Upper Oligocene marine beds penetrated in bores further to the east. This evidence appears to be reasonably sound if the lignites penetrated in the eastern bores may be correlated approximately with those of the Morwell district, and Sussmilch's claim that the Morwell lignites may pass upwards into the Lower Pliocene has little bearing on the age of the basalts, since these occur near the base of the series (Edwards, 1938).

By avoiding any attempt at correlation of the definitely Pre-Miocene Older Volcanics of the Mornington Peninsula and Melbourne District with those of Berwick and South Gippsland, Sussmilch minimizes the evidence that the former afford as to the age of the latter. This procedure is not justified, however, for the lavas of the Mornington Peninsula are separated from those of South Gippsland only by the Koo-wee-rup swamp, which is an area depressed by late Tertiary faulting, during which, as shown by boring, the basalts were thrown down to 436 feet below sea level at Lang Lang. There is no reason to doubt that before the faulting a more or less continuous lava field stretched from Drouin and Heath Hill to the Peninsula (Keble, 1918), with outlying residuals as at Berwick and Mt. Ararat, east of Berwick.

As in South Gippsland, leaf beds are associated with the lavas on the Mornington Peninsula and also in the Melbourne district. The continuity of physiographical conditions is obvious, and there can be little doubt as to the similarity of age. This is shown to be Lower or pre-Miocene by the evidence of bores at Tooradin and surface geology near Melbourne, so it may be concluded that, of the lavas specifically referred to as Lower Pliocene by Sussmilch, the Tanjil, Tanjil East, Narracan, Berwick, Morwell, and Aberfeldy occurrences are in reality Lower Miocene or Oligocene, and would therefore be referred to the Older Volcanic Series, as is generally recognized in Victoria.

Physiographically these lavas are characterized by their mature dissection, and the fact that they have been affected by block faulting of probable Middle or Upper Pliocene date (Hills, 1935). South of the Eastern Highland boundary the lavas have been elevated to 1,500 feet above sea level in the South Gippsland Highlands, and depressed 300 feet below sea level, beneath the Gippsland Plain at Yarragon. Where they have been exposed at the surface in these districts, all initial superficial features of the flows have been completely obliterated, and such centres of eruption as have been recognized have been completely degraded, no longer retaining the form of hills of accumulation (Edwards, 1934).

North of the Gippsland Plains, on the southern slopes of the Eastern Highlands, block faulting is no longer important, and residuals such as the Tanjil series and those on the interfluve between the Aberfeldy and Thomson Rivers slope gradually downwards towards the plains where they pass beneath Tertiary sediments. These residuals are maturely dissected, and again no initial superficial features are preserved. Their physiographic setting is shown in the block diagram (Fig. 1). In all essentials the authenticated Older Volcanics of the Melbourne district show physiographic features comparable with those above described for the Gippsland lavas.

The Cainozoic Lavas of the Eastern Highlands.

Morass Creek.—The lavas of the Morass Creek extend from Uplands, about 6 miles north of Benambra township, to the Gibbo River, a distance of about 10 miles. They have been mapped by Stirling (1888), who classed them simply as Tertiary, but on the 1902 geological map they are shown as Newer Volcanic, while on later maps they are shown as Older. Skeats (1910) followed the later maps, referring them to the Older Volcanic Series, and Murray (1908) did the same. In recent publications, however, Thomas (1937, pp. 572-575) and Kenny (1937, pp. 461-464) have briefly indicated the physiographic youth of the lavas, and Easton (1937,

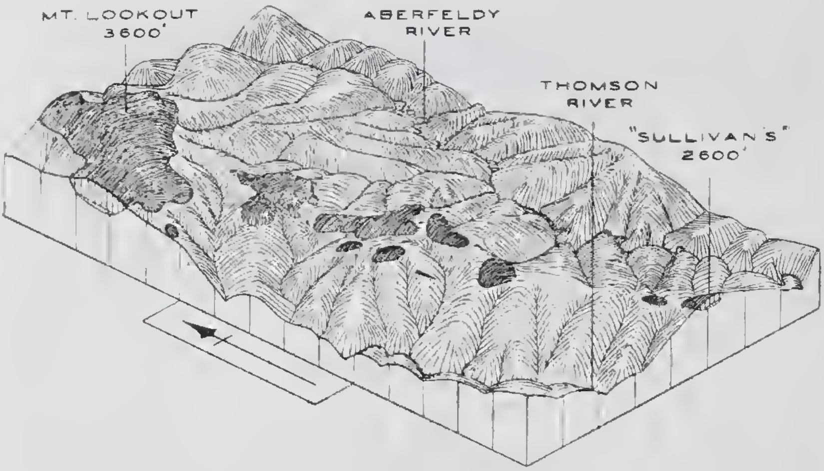

Fig. 1.—Block Diagram to illustrate the physiographic setting of the Older Volcanic lava residuals betwen the Thomson and Aberfeldy Rivers. Approximate scale North-South, 1 in. = 1½ miles.

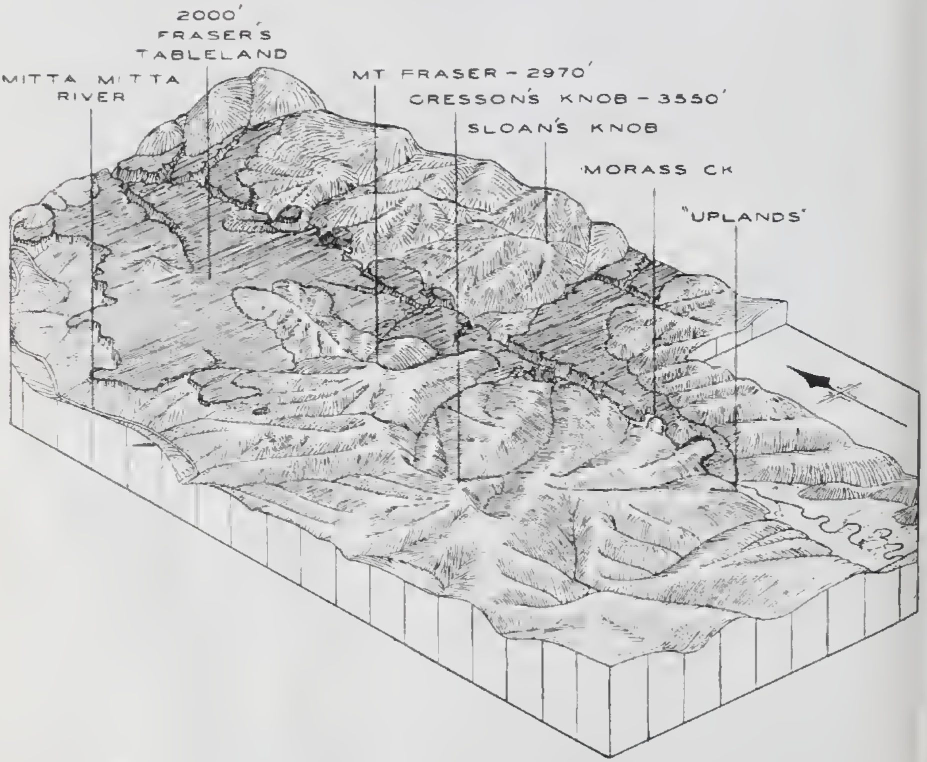

Fig. 2.—Block Diagram to illustrate the physiographic setting of the Morass Creek basalts. Approximate scale North-South, 1 in. = 1½ miles.

p. 507) actually refers to them as Newer Basalts. I visited the district in 1937, and the following account is based mainly on personal observation.

The valley of Morass Creek has been excavated in hard Palaeozoic rocks, mainly slates, conglomerates, gneisses, and porphyries. In the neighbourhood of Benambra the valley floor is broad and marshy with a shallow lake adjacent to the town, on the eastern side of the low ridge separating the basin of Lake Omeo from Morass Creek. The alluviated portion of the valley narrows to the north (downstream) and at Uplands the Morass Creek basalts are to be seen. From this point downstream to the Gibbo River, the main valley floor is occupied by lavas, several superposed flows being recognisable in cliff sections. All the specimens examined petrologically are basalts, and it will be convenient to refer to the suite as the Morass Creek basalts.

As is shown in the block diagram (Fig. 2), the walls of the pre-basaltic valley rise high above the lavas, which flowed both up and down the valley of the pre-existing stream, probably from a centre of eruption marked by the hill rising above Fraser's Tableland. They also flowed up the valleys of tributary streams, and, as Easton has shown, up the valley of the Gibbo River for a distance of about 5 miles, where they dammed the river and initiated a lake in which extensive deposits of alluvium were laid down (1937, p. 508). The flat-topped lava plateaus such as Fraser's Tableland, with their surfaces dotted with boulders of vesicular basalt, are reminiscent of many of the young lava plains of Western Victoria, and, as in this district, the stage of dissection of the flows is youthful. The Morass Creek has now cut a gorge, mainly along the eastern edge of the basalts, but over extensive areas the initial surfaces of the upper flows are but little modified by erosion.

A feature strongly indicative of youth is the preservation of the broad alluvial flats upstream from Uplands. Topographic data supplied by the maps of the State Electricity Commission show that the whole of the alluviated reach lies below the level of the top of the basalts and is indeed almost a horizontal plane surface. There can be no doubt that these flats were deposited in a lake formed by the damming of Morass Creek by the basalts. Although this lake has been drained owing to the lowering of the basalt barrier as the creek has become incised into it, large areas are still marshy, and near Benambra a small lake still remains. It is only in the actual vicinity of the barrier that the flats are now beginning to be removed by the stream.

It will be clear that the Morass Creek basalts are in no way comparable physiographically with the typical Older Volcanics of the key areas. The Aberfeldy residuals, which lie at approximately the same elevation above sea level as the Morass Creek flows, afford a standard for comparison (see Figs. 1 and 2), and

the vastly greater denudation that these Older Volcanics have suffered under comparable physical conditions indicates the relative youthfulness of the Morass Creek flows. In the preservation of the lacustrine deposits, the slight degree of modification of the initial surface features of the flows by erosion, the existence of a hill of accumulation at the probable point of eruption, and the youthful nature of the Morass Creek where it traverses the lavas, they resemble the Newer Volcanic basalts that occupy the valley of the lower Yarra, which will later be shown to be probably Pleistocene in age.

In view of the fact that they are situated at an elevation of more than 2,000 feet above sea level, it may be assumed that the Morass Creek basalts are perhaps even younger than those of the Yarra valley. In any case, the conclusion is unavoidable that they are late Cainozoic, and thus referable to the Newer Volcanic Series. A short account of the petrology of the basalts will be found in the Appendix.

Gelantipy.—The Cainozoic lavas of this district lie on the tableland between the Murrendal River on the west and the Snowy River on the east, about 2,000 feet above the latter stream (Ferguson, 1899). They extend for about 20 miles as a north-south strip, commencing from a point about 10 miles north of Buchan. According to the reports of Ferguson, and Brough Smyth's account of Murray's explorations (1875, p. 5), the basalt ends in escarpments along the Snowy River, but hills of porphyry and Devonian limestone rise above the flows. Ferguson mentions the occurrence in shaly layers of the wash beneath the lavas, of leaf impressions "resembling Miocene forms" (1899, p. 21). Howitt (1879) at first regarded the lavas as Newer Volcanics, and they were marked as such on the 1902 map, but Dunn (1907) referred to them as Older Volcanics, and they have been marked as such on later maps. Petrologically all the specimens examined may be broadly described as basalts (see Appendix), and the suite will be referred to herein as the Gelantipy basalts.

The physiographic features shown by these lavas, where I examined them near Gelantipy, are certainly not as youthful as those of the Morass Creek basalts. In the Gelantipy district they do, however, still lie below the level of the walls of the pre-basaltic valleys, and it is clear from the above descriptions that they are also lower than remnants of the pre-basaltic interfluves in other places. The Snowy River is well known to be a particularly powerful stream, and Ferguson's account shows that it is physiographically youthful in the area under consideration. In places the walls of its gorge are only 30 feet apart. Thus, it is quite conceivable that its 2,000 feet deep valley should have been excavated along the edge of the basalt flows during a relatively short period. At Gelantipy the dissection of the flows is much less advanced than that of the Older Volcanic residuals at Aberfeldy

and Tanjil, being comparable with that of many of the Newer Volcanic lavas on and near the divide in Central Victoria. I consider, therefore, that the Gelantipy basalts are younger than the Older Volcanics of South Gippsland. They are, however, older than the Morass Creek basalts, since the initial surface features of the flows have been much modified by erosion, and I would suggest that they are probably comparable in age with the Pliocene members of the Newer Volcanic Series, which will be described later.

South Buchan.—The small patch of basalt (see Appendix) occurring at this locality lies at an elevation of less than 1,000 feet above sea level. The surface features are largely obscured by soil, and it is possible that the existing occurrences are only remnants of larger flows.

On some of the hills both north and south of Buchan, high-level fluviatile gravels and sands occur that one would class, in the absence of definite evidence, as probably Pliocene, by analogy with the alluvial leads in Western Victoria. The Pliocene Torrent Gravels of the Gippsland Plain, too, extend up for some miles into the southern part of the Eastern Highlands as hill cappings up to 600 feet above sea level (Howitt, 1875), and it is not unreasonable to suppose that the Buchan gravels are of similar age to these. On a hill a few miles south of Buchan a thoroughly decomposed basic dyke, well exposed in a road cutting, cuts the gravels, and what appear to be lenticular basic flows, now also decomposed, are interbedded with them. In the absence of more definite evidence concerning the age of the gravels, it would be hazardous to assume a Pliocene age for the dyke and interbedded flows, or to relate them to the South Buchan basalts. The impression gained in the field is, however, that the latter may be even younger than the hill cappings of gravel, as they occur at lower levels than these, and also lie below the neighbouring hills of Devonian limestone. Although very indefinite, the indications are that the South Buchan basalts may perhaps be regarded as Upper Cainozoic or at least younger than the Oligocene and Miocene Older Volcanics of South Gippsland. Howitt (1879) mentioned them as Newer Volcanics, Murray (1875) as Older, and they were shown as Newer on the 1902 map, but Older on the 1908 and later ones.

Euroa.—In the valley of the Seven Creeks, from about three miles south of Euroa for a distance of seven miles upstream, there is an isolated patch of Cainozoic limburgites (see Appendix) which like those occurrences above discussed, was marked as Newer Volcanic on the 1902 map, and Older Volcanic on later maps. Dunn (1914) has given a very brief account of these lavas, referring to the presence of scoria and ash beds and small volcanic cones. From personal observation, I would confirm Dunn's remarks as to the recent appearance of the flows in this

district, though in a rapid examination of the district I was unable to discover any scoriae or ashes. This small lava field occupies the floor of the main valley of the Seven Creeks, which is deeply incised into the surrounding granitic tableland of the Strathbogie Ranges. Both dense and vesicular varieties of the limburgites occur, and many of the small flows have the peculiar ridge-like form of the Western District stony rises. Two rocky prominences near the confluence of the Wombat and Seven Creeks are probably among those referred to as points of eruption by Dunn, but their real nature is not absolutely certain. They break suddenly up from the surrounding well grassed plains, and ridges suggesting flows emanate from them.

If they merely represent residual hills owing their rocky character to some initial difference in texture of the flows, it is difficult to explain the almost complete absence of limburgite boulders in the creeks, which are filled with sand from the neighbouring granites. In any case, the position of the lavas in the floor of the main valley, and the lack of co-ordination of the drainage in the lava-filled section of this valley, are clear evidence of the youth of the flows, and they are to be correlated with the younger members of the Newer Volcanic Series.

Although I have not investigated in detail any of the other patches of Cainozoic lavas in the Eastern Highlands, it may be pertinent to summarize such information as is available concerning them.

At Glenmaggie basalts whose relationships to the Tertiaries of the Gippsland plain are uncertain but which still lie below the level of the interfluves of the pre-volcanic streams, have been described by Murray (1877), who compared them with the Older Volcanics of Tanjil (p. 56). Mr. Baragwanath informs me, however, that he considers the Glenmaggie basalts to be younger than the typical Older Volcanics of South Gippsland, since they do not occur as residuals capping the hills, but lie in the pre-basaltic valleys, whose walls in places rise above them.

Owing to their association with the *Cinnamomum* flora, the Dargo and Bogong basalts must be regarded as not younger than the Lower Pliocene, and possibly as of greater antiquity than this, since this flora was already well developed in Oligocene times (see p. 124). Hunter (1898) considered that there is evidence of two flows in places, with an erosion interval between them. Mr. M. A. Condon has recently surveyed portions of these High Plains, and has kindly supplied me with a sketch section showing the mode of occurrence of a small patch of scoriae, agglomerate, and tuffs with associated lavas, at Roper's Lookout, near Mt. Cope. He considers the section to be portion of a denuded volcanic cone, and if this is substantiated by later work, it would constitute the first record of its kind in the High Plains. Occurring as it does as an isolated patch some

distance from the main lava residuals, the occurrence has no direct bearing on the age of the latter. It does indicate, however, the possibility that late Cainozoic volcanic activity may have taken place in the district, for it is unlikely that a superficial and easily erodable deposit such as these pyroclastic rocks afford, would have been preserved under the conditions of strong denudation that obtain in the High Plains, since early or middle Cainozoic times.

Finally at Mahaikah, petrologically typical Older Volcanics overlie lignities of possibly Oligocene or Lower Miocene age (Edwards, 1938).

It will now be clear, firstly that definitely Newer Volcanic rocks occur in the Eastern Highlands, at Morass Creek and Euroa, and possibly also at Roper's Lookout, near Mt. Cope. Authentic Older Volcanic flows also occur at Mahiakah, in the Aberfeldy, Tanjil, Berwick, and other districts, and also in the South Gippsland Highlands, and in the Gippsland Plains. The Dargo and Bogong High Plains may have flows of several different ages, but the main suite is perhaps to be classed with the Older Volcanic Series. The Gelantipy and South Buchan basalts and also those of Glenmaggie are of doubtful age, but the available evidence indicates that they are intermediate between the Morass Creek basalts and the Older Volcanics of South Gippsland, and may provisionally be regarded as Newer Volcanics.

III. The Cainozoic Volcanic Rocks of Western Victoria.

In recent publications Singleton (1935), Sussmilch (1937), and Jutson and Coulson (1937) have discussed in general terms the question of the age of the so-called Newer Volcanic Series in the area west of the meridian of Melbourne. There is general agreement that some of these rocks are of Recent age, but while Singleton and also Jutson and Coulson place the main period of extrusive activity in the Pleistocene, Sussmilch regards is as Lower Pliocene. Coulson (1938) has defined with some precision the ages of several individual flows in the Geelong district, the ages assigned ranging from Upper Pliocene to Pleistocene.

The stratigraphic data used to determine the ages of the volcanic rocks by these authors differ to some extent. Sussmilch relies mainly upon the evidence of the deep lead floras such as those of Pitfield Plains and the Haddon lead, but makes use also of Keble's interpretation of the geology of the Drik Drik district, and physiographical evidence. Jutson and Coulson base their conclusions upon the relationship of the basalts to the old consolidated Pleistocene dunes, the Lara and Limeburner's Point limestones, the shell beds described by them at Portarlington, and on their interpretation of the history of the Port Phillip area

during late Cainozoic times. Largely as a result of their interpretation of the Portarlington beds, they reach conclusions as to the coastal geology of the Port Phillip area which diverge widely from those formerly accepted, and would necessitate, if accepted, very considerable modification of our ideas as to the physiographic evolution of this area. References to most of the older literature are to be found in the above works, also in Walcott's paper (1920) on the age of the auriferous drifts, and in Hunter's account of the deep leads (1909).

The Evidence of the Fossil Floras.

As a result of his survey of the deep lead floras, Sussmilch draws the conclusion that the fruits and leaves occurring beneath or interbedded with the lavas of Dargo, Narracan, Berwick, Morwell, Bacchus Marsh, and Pitfield, in Victoria, Vegetable Creek and Dalton in New South Wales, and the Redbank Plains in south-eastern Queensland, belong essentially to a single floral association called by him the *Cinnamomum* Flora. Although he recognizes that some of the members of this flora existed in pre-Pliocene times, perhaps even in the Miocene, he concludes that the flora was "abundant and widespread in Pliocene times", and would regard most of the lavas associated with the flora as Lower Pliocene. This position seems to me to be untenable, for if the evidence from the bores in East Gippsland, above referred to, may be taken as demonstrating the Oligocene or Miocene age of the Yallournian lignites, then the *Cinnamomum* Flora must have been already well established in these periods. In view of Sussmilch's claim that the flora is more characteristic of the Pliocene than of older periods, the further evidence of its antiquity afforded by the Redbank Plains beds, in Queensland, is significant. There, *Cinnamomum* and other members of the flora are associated with fresh water fish remains, which I have referred, with some reservation, to the Oligocene (1934). Sussmilch, however, discounts the evidence of age afforded by the fishes, noting that *Epiceratodus denticulatus*, from the Redbank Plains beds, is close to the Pleistocene and Recent *E. forsteri*; that *Phareodus queenslandicus* is a new species and thus perhaps of little stratigraphical value; that *Notogoneus parvus* is of doubtful generic position, and that *Percalates antiquus* closely resembles the living *P. colonorum*. I have, however, gone further into the evidence of age afforded by these fishes, and have no reason to doubt their Lower Tertiary age.

It may be pointed out that all other known species of the genus *Phareodus*, as well as the related genus *Musperia* (Sanders, 1934), which occurs in Sumatra, are restricted to the Eocene. Furthermore, the distinction between *P. queenslandicus* and the Eocene *P. testis*, from North America, so far as I have been able

to judge from published descriptions and from photographs kindly supplied by the Museum of Comparative Zoology, Harvard, and the American Museum of Natural History, New York, is based only on differences of a minor nature. They reside chiefly in the number of vertebrae, which may vary within the limits of a single species, and the dentition, which is largely developed in response to feeding habits: I have not been able to compare the squamation. In referring the Queensland species to the Oligocene I have made some concession to the evidence of a younger age for these beds, which is afforded by the presence in them of *Epiceratodus* and *Percalates* (see below).

Concerning the doubtful generic position of the Gonorhynchid, *Notogoneus,* upon which Mr. Sussmilch comments, I consider that the essential point for our present purposes is not the generic position of the fish, but the fact that we have to deal with a member of a well-defined group within the family. This group, which includes *Notogoneus* (with which the Queensland example is undoubtedly closely allied), *Colpopholis* and *Phalacropholis* of Europe and North America, is confined to fresh water deposits, whereas the living members of the family are marine. These fresh water Gonorhynchids range from Ypresian (Eocene) to Rupelian (Oligocene) (see Chabanaud, 1931), and there are therefore strong grounds for referring the Redbank Plains beds to one or other of these Lower Tertiary periods.

Although *Percalates antiquus* resembles the living *P. colonorum* very closely, I cannot agree that this indicates a younger age than I have suggested. The osteological characters of Percoid fishes are remarkably stable, even generic distinctions being based, when osteological characters are used as a criterion, on such minor features as the nature of the spines on the pre-operculum (see Woodward, 1901, p. 504). Thus, the Eocene *Cyclopoma* is distinguished from the living *Lates* solely on differences in these spines, and as the differences between *P. colonorum* and *P. antiquus* are of a higher order than this, though in my opinion not such as to warrant generic separation, I think it is reasonable to assume that the fossil species is not, of necessity, to be regarded as Upper Tertiary. Little can be said concerning the Dipnoan, *Epiceratodus denticulatus,* in view of the fragmentary nature of the remains, but it may be remarked that *Epiceratodus* ranges down into the Cretaceous (White, 1926), and as the Redbank Plains fish is distinct from *E. forsteri,* its occurrence in presumably Oligocene beds is not inconsistant with the known facts.

In view of these considerations, I think it is justifiable to rely mainly on the Osteoglossid and Gonorhynchid as index fossils, since these give definite evidence of age, in so far as our present knowledge goes. These forms indicate an Eocene

or Oligocene age, and in suggesting the latter I have made some concession to the claims of the other species. In my opinion it is preferable to regard the evidence from the Redbank Plains as indicating the antiquity of the *Cinnamomum* flora, rather than the youth of the fish remains.

The *Cinnamomum* flora is essentially an Australian one (Deane, 1901), and includes not only genera (e.g. *Cinnamomum*) that are restricted to-day to the warmer and moister parts of the continent, but also genera such as *Casuarina* and *Eucalyptus* that still live in Victoria. It is clear, therefore, that climate or topographic changes have caused the dying out of the sub-tropical types in Victoria, while other genera have lived on in spite of such changes.

I have already shown (1935) that during the Pliocene, important earth movements took place in Victoria, and it may be that the existing floral association was initiated during and after these movements, which may have been accompanied by a climatic change. *Cinnamomum* itself is known to occur in beds at Beaumaris that may be either Lower Pliocene or Upper Miocene in age (Singleton, 1935), but there is no evidence of its occurrence in Victoria in beds shown by the evidence of marine fossils to be younger than the Lower Pliocene.

Due allowance being made for the incompleteness of the fossil record, it may be assumed, therefore, (1) that *Cinnamomum*, and other genera belonging to Deane's "brush" type of flora, not now living in Victoria but found in the warmer and moister parts of Australia, serve to indicate an Oligocene, Miocene, or possibly Lower Pliocene age; and (2) that an "open forest" flora from which the above types are absent, but which includes *Eucalyptus*, *Banksia*, *Casuarina*, and other genera now living in the State, indicates a post-Lower Pliocene age. The possibility must also be considered that communities of the older flora may have persisted locally under favourable conditions into post-Lower Pliocene times, especially along the southern portions of the Eastern Australian Cordillera, in New South Wales.

In view of these conclusions, the association of the *Cinnamomum* flora with volcanic rocks at Glenfine, south of Pitfield, assumes considerable importance. Sussmilch (1937, p. xvi) accepts this association at its face value as indicating that all the basalts at Pitfield, including the upper flows which are typical members of the Western District suite, are Lower Pliocene in age. Walcott (1920, p. 86) considers that the basalts may be even older than this, being Middle or Lower Tertiary, since they "must have had [their] origin in the same period" as the leaf beds and the gold drift.

Chapman and Singleton (1923, p. 14) have indicated, however, that the lower basalts at Glenfine are probably Older Volcanics, and this view has much to support it. The section at Glenfine

is shown in Figure 3. There is only a patch of about 40 acres where the lower lavas occur (Hunter, 1901), and it will be noted that these occupy a valley eroded in the bedrock. The upper of the two basal flows has, in all probability, been planed down by fluviatile erosion to the level of the rock floor upon which the Pitfield wash rests, and the 40-acre patch of lower basalts must represent only a remnant of formerly more widespread flows. There is thus a considerable time gap between the upper flow and those that underlie it, so that the leaf beds do not prove the superficial lavas of the district to be Lower Pliocene or older.

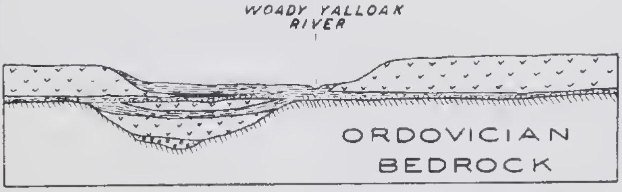

Fig. 3.—Section showing the relationship of the upper and lower lavas at Glenfine Consolidated Mine, Pitfield Plains. The leaf beds with *Cinnamomum* occur between the two lower flows. The auriferous Pitfield wash lies beneath the upper flow. Horizontal scale, 1,600 ft. = 1 in.; vertical scale, 800 ft. = 1 in., datum 140 ft. above S.L. (After Hunter, 1901.)

It remains now to consider the age of the fruit-bearing leads that in places underlie Cainozoic lavas in the Haddon, Nintingbool, Tanjil, Rokewood, and other districts, in relation to that of the *Cinnamomum* Flora, and of the leads with *Eucalyptus*, *Banksia*, and fossil wood, such as those of Creswick and Eldorado. I believe it to be unlikely that von Mueller's determinations of the affinities of the various fruits he described are to be relied upon, as Deane has shown that certain of his species are allied to living Australian genera, so that there is little point in discussing at length their stratigraphical significance. It is clear that some of the plants from which the fruits were derived existed in Oligocene or Miocene times, since they occur under the undoubted Older Volcanics of Tanjil, but neither their upper nor their lower limit has been precisely defined, and it may be that some of them ranged above the Lower Pliocene, which, as has been shown above, may be regarded as the upper limit of the *Cinnamomum* Flora in Victoria. The Haddon fruit-bearing leads are in all probability younger than the *Cinnamomum* beds of Pitfield (see p. 131).

The Evidence of the Pleistocene Dunes.

At several places around the Victorian coast, from Barwon Heads to Portland, Cainozoic volcanic rocks come into stratigraphic relationship with consolidated calcareous sand dunes

that are generally accepted as Pleistocene in age, though Jutson and Coulson regard them as ranging from Upper Pleistocene to Recent (1937).

The Quaternary stratigraphy of Victoria is not known in sufficient detail to enable the age of the dune rocks to be determined by direct evidence, but if the theory propounded by Sayles (1931) to account for the formation of the remarkably similar ancient dunes of Bermuda be accepted, then it may be possible to arrive at the age of the Victorian dunes by analogy. Having found by detailed studies that there were five periods of active dune-building in Bermuda, separated by periods of soil formation, Sayles correlated the former with periods of maximum ice-cap development during the Pleistocene, and the latter with inter-glacial epochs. It is suggested that, as the waters of the oceans were lowered owing to the growth of ice caps, the broad tracts of sandy sea floor so exposed supplied the material for forming the dunes, and that during inter-glacial and post-glacial times the re-advance of the sea caused active dune building to cease. On this hypothesis, Pleistocene dune-building should have been a world-wide phenomenon, and if it should prove possible to correlate the periods of dune building with those of maximum ice cap development, then the old dunes would form a very convenient geological time scale in non-glaciated regions. Daly (1935) has interpreted the old dune series described by Durègne in Gascony along those lines, and it is interesting to note that Darwin (1876) has compared the consolidated dunes of King George Sound, in Western Australia, with those of the Cape of Good Hope, Madeira, and Bermuda, also noting (p. 99) that the dune limestones of St. Helena must have formed when that island was surrounded by a shelving coast quite unlike its present precipitous shores. Tate (1879) was also impressed with the necessity for postulating a lowering of sea level, which would produce a shelving sandy coastline, to explain the formation of the Pleistocene dunes at the head of the Bight.

The conditions postulated by Sayles and Daly would admirably explain the formation of the old dune series in Victoria. At times of maximum glaciation large tracts of Bass Strait would have been above the sea, and the masses of comminuted shells so exposed would have been blown by southerly and south-westerly winds over the present coastal fringe of Victoria, and the islands in Bass Strait.

On nearly all the islands in the Strait that were examined by Johnston (1888) old consolidated sand dunes occur up to a height of 100 feet above sea level. These old dunes are dominantly composed of fragments of marine shells, but owing to the presence in them of bands rich in various species of land snails such as *Helix*, *Succinea*, etc., Johnston named then the *Helicidae*

Sandstones. Myriads of individuals belonging to various species of these genera live to-day on the vegetation cover of the dunes, and their shells are washed into hollows, forming layers like those found in the dunes themselves. Johnston classed the dunes as Recent in the Table on p. 303 of his book, but listed certain of the fossils obtained from them as Pleistocene (p. 329). David (1932, Table I.) referred them to the base of the Recent period.

Around the south coast of Australia, in Victoria, South Australia, and Western Australia, the old consolidated dunes exhibit similar features to the *Helicidae* Sandstones. At Cape Schanck and Barwon Heads ancient soil layers formed during periods of cessation of dune building are rich in fossilised shells of *Helix* and other land gasteropods, Pritchard (1895) having recorded *Helix* and *Bulimus* from Barwon Heads and also from a point about a mile west of the Gellibrand River. Tate (1879) has referred to similar occurrences of *Helix* and *Bulimus* in the old dunes at the head of the Bight, and Darwin (1876, p. 163) recorded *Helix* from St. George's Sound, where the shells "abound in all the strata." These fossils have no stratigraphical significance since they have not been studied in detail, but they do indicate that the dunes were formed at these different localities under comparable physiographical conditions. All observers are agreed that the consolidated dunes are older than the coastal dunes now forming, and since it is necessary to postulate a different coastal topography from that which now exists, in order to adequately explain their development, it appears to me to be a reasonable assumption that they formed during the world-wide depressions of sea level that occurred during the Pleistocene glaciations.

A noteworthy feature of the old dunes is their division into roughly horizontal layers whose upper and lower surfaces truncate the planes of cross-bedding. This is well shown at Barwon Heads, Cape Schanck, and Cape Otway, and has been described by Wilkinson (1865), Griffiths (1887), and Coulson (1935) in Victoria, and by Tate (1879) in South Australia. These sub-horizontal layers represent periods of cessation of active dune building, during which friable sandy soils, white travertine bands, or black rubbly carbonaceous layers were developed.

At Barwon Heads there is evidence of the presence of five such periods of soil formation after the commencement of the formation of the dunes and before the present day. Without detailed study it would be unsafe to correlate them even tentatively with inter-glacial epochs, as Sayles does with the Bermuda dunes, but consideration of the record of the Sorrento bore (Chapman, 1928) does suggest that the Pleistocene period exhibits in Victoria

a succession of periods of dune building with intervening periods of sand stability, and it may be tentatively assumed, therefore, that the old dunes of the Victorian coast range throughout the Pleistocene. Detailed studies will be necessary to confirm this, but in what follows, formations which are overlain by the consolidated dunes are referred either to pre-Pleistocene or Lower Pleistocene times. This view is opposed to that of Jutson and Coulson, who place the lower portions of the dune series in the Upper Pleistocene, and its upper portions in the Holocene (p. 323). On the view put forward here, the dunes would cease to form when the last ice maximum passed, so that it is only the unconsolidated, and usually very restricted dunes now in process of formation that would be classed as Holocene.

Where the Cainozoic volcanic rocks come into relationship to the Pleistocene dunes, as at Portland, Port Fairy, Warrnambool, and Barwon Heads, we find that the lavas underlie them, but between Port Fairy and Warrnambool, tuffs from Tower Hill overlie them. Clearly, therefore, the Tower Hill tuffs must be classed as late Pleistocene or Recent, and this view has always been the accepted one. The lavas, on the other hand, must be placed either within the Lower Pleistocene, if the dunes do not cover the whole of Pleistocene time, or in pre-Pleistocene times if the base of the dunes is Lower Pleistocene. Since the lavas are nowhere interbedded with the dunes, there are good grounds for assigning to them a pre-Pleistocene or basal Pleistocene age. This conclusion, of course, refers only to the flows at the particular points mentioned.

IV. Regional Summary of Occurrences.

West of the Hopkins River and Bushy Creek.

In the Portland district, basalts, in places deeply weathered and locally associated with tuffs (Kitson, 1906; Dennant, 1887), occupy valleys eroded through Barwonian limestones and through an oyster bed. The latter was referred to as Miocene by Dennant, but was doubtfully correlated with the Ostrea Limestone that conformably overlies the Werrikooian shell beds along the Glenelg River by Singleton (1935). If the Ostrea bed at Portland is Werrikooian, which is not certain, the basalts must be regarded as epi-Pliocene, for they are overlain by Pleistocene dunes at Cape Bridgewater. In places they have a thin capping of sand (Kitson), and have been extensively eroded by the sea along the coast.

Basalts which are probably older than the Portland flows, and form dissected plains and residual ridges, occur at Mt. Clay and the Kangaroo Range, Drik Drik. At the latter locality (see geologically coloured Parish Plan, Drik Drik; also Keble's

remarks in Sussmilch, 1937) the basalts appear to be pre-Werrikooian and are certainly post-Barwonian. These occurrences are outlying patches of a dissected lava plain stretching from the coast northwards to Branxholme, Hamilton, and Dunkeld, and east to the Hopkins River. At Hamilton they overlie marine Kalimnan beds, and they form a physiographically well-defined unit (see Block Diagram, Fig. 4) characterised by deep dissection, especially in the north, and strong weathering. They may therefore be grouped together as post-Lower Pliocene (Kalimnan) and pre-Pleistocene, perhaps pre-Upper Pliocene if their relations to the Werrikooian are correcly interpreted. They may therefore be regarded as Middle Pliocene.

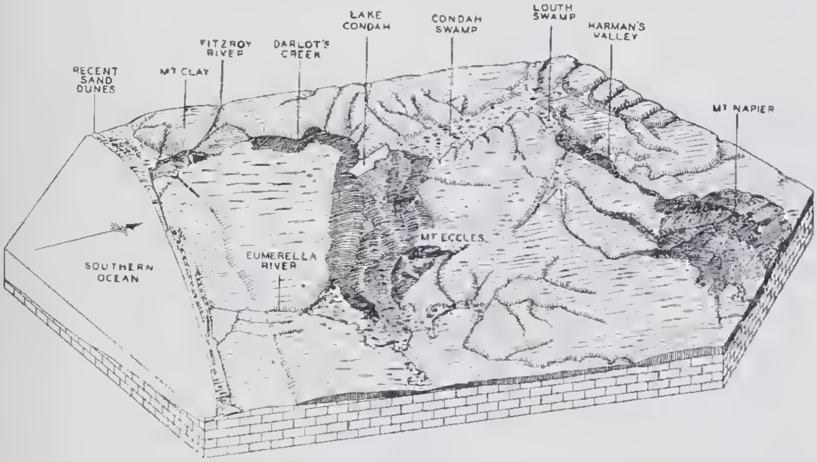

Fig. 4.—Block Diagram to illustrate the physiography of portion of the Western District lava plains. The bedrock, shown diagrammatically, consists of Miocene limestones. These are overlain by maturely dissected Middle Pliocene lavas, except near the coast where the limestones appear at the surface. The Stony Rise flows from Mt. Napier (1,440 ft.) and Mt. Eccles (580 ft.) are shown schematically. Approximate scale North-South, 1 in. = 13 miles.

The Stony Rises.—As shown by Mahony and Grayson (1910. Skeats and James (1937), and by Sussmilch (1937), there are at several localities in the Western District, flows of very recent appearance, which are known as Stony Rises.

In the district under consideration such flows occur around Mt. Napier, Mt. Eccles, and Mt. Rouse. That they are considerably younger than the older lavas referred to above is clear from the fact that, as at Byaduk and the Fitzroy River, they flowed down valleys cut into these lavas. The flow down Harman's Valley, at Byaduk North, appears to be the youngest in the district. At its lower termination, near Wallacedale, it spread out as a wide sheet over the upper reaches of the Condah Swamp, there known as the Louth Swamp, where a remarkable group of

low domes, or "lava blisters," was formed by the expansion of water vapour imprisoned beneath the flow, as shown by Skeats and James. The Condah Swamp itself was caused by the damming back of Darlot's Creek by flows from Mt. Eccles, so that the Harman's Valley flow is younger than these latter. Details of the initial surface features of the flow are still perfectly preserved and there can be no doubt as to its Holocene age. As the other Stony Rises around Mt. Napier have exactly similar relationships to the pre-existing, dissected lava plain as does the Harman's Valley flow, they and the compound scoria cone at the summit of the mount, with its well developed breached crater on the western side, are also to be referred to this period. On the lower flanks of Mt. Napier, on the northern and eastern sides, there are perfectly preserved low scoria cones which are also undoubtedly Holocene.

Mt. Eccles is situated on the northern border of a large and roughly rectangular area of Stony Rises, extending between Darlot's Creek, on the west, and the Eumerella River on the east. A long lava tongue extends southwards from Lake Condah nearly to the coast, separating the Fitzroy River flowing along its western margin from Darlot's Creek along its eastern, until the two streams unite at the termination of the flow. Physiographically these Stony Rises are exactly comparable with those around Mt. Napier, as they occupy, or have over a large area actually obliterated, valleys eroded through the older, presumably Pliocene lavas and the Barwonian limestones that appear along the coast, and they preserve their initial surface features in perfect detail. They dammed back Darlot's Creek, forming the shallow Lake Condah and the Condah Swamp, and are also responsible for the formation of the swamps along the Eumerella River south-west of Macarthur. These features are all indicative of extreme youth, and the flows must be classed as Holocene.

Around Mt. Rouse, Stony Rises of recent appearance exist close to the scoria cone itself, but the flows extending southward for about 10 miles from Penshurst, although physiographically younger than the older flows of the Hamilton and Portland district, are not typical Stony Rises. They appear to be intermediate in age between the Recent flows and the more deeply dissected lavas near Port Fairy that pass beneath the dune limestones, for although they have been weathered much more deeply than the Stony Rises, their topography still reflects in large measure the configuration of individual flows. Nearer the coast stream dissection is important in determining the topography. The Moyne Swamp was not caused by interruption of pre-existing drainage lines by the lavas, as was the Condah Swamp, but occupies a sagged area, perhaps connected with the solution of underlying Tertiary limestones. Since the lavas near the coast

pass beneath the Pleistocene dunes at Port Fairy (Ferguson, 1920). I would suggest that they are to be correlated with the Pliocene flows further west. The Stony Rises near Mt. Rouse are, by analogy with the occurrences at Mt. Napier and Mt. Eccles, to be regarded as Holocene, and the flows south of Penshurst are therefore possibly Pleistocene.

As already indicated, the tuffs from Tower Hill overlie the Pleistocene dunes, forming a layer of variable thickness that follows the topography of the underlying dunes at least as far east as Warrnambool, and west to Port Fairy. Tuffs cover the whole of the Tower Hill Swamp and the marsh north of the Barwonian limestone ridge that runs easterly from Tower Hill, and they also overlie Recent shell beds (Brough Smyth, 1858). The Recent age of the tuffs is thus confirmed.

The District between the Hopkins River and Inverleigh.

The youngest flows in this district are typical Stony Rises, which by analogy with those above described are to be regarded as Holocene. They are developed around Mt. Porndon, the Warrion Hills, and Red Rock (Skeats and James, 1937), and also around Mt. Elephant, Mt. Leura, and Mt. Terang (Mahony and Grayson, 1910). Large areas of the southern portion of this district are covered by tuffs which in places contain or overlie remains of extinct marsupials. At Mamre Station a fossil fern, *Pteris aquilina*, has been obtained from them (Mahony and Grayson, 1910). Although it is often assumed that the giant extinct marsupials are characteristically Pleistocene, Walcott (1920) has shown that they may range from Pliocene to Holocene, so that they cannot be used as index fossils. The tuffs at the Warrion Hills, Red Rock, and Mt. Porndon that overlie the Stony Rises must be Holocene, and those covering the floors of lakes and swamps south-east of Mt. Shadwell and near Camperdown are also probably of this age, as they form a mantle over the countryside like those of Tower Hill, and overlie clays from which an artefact was obtained at the Pejark Marsh (Walcott), 1919).

The older lavas of this district, which are characterised by more extensive weathering, the development of buckshot gravels, and by their dissection by streams have been referred to the Lower Pliocene by Sussmilch, and an even earlier age, perhaps Miocene or older, by Walcott (1920). The evidence adduced by these authors is afforded by the leaf beds at the Glenfine Extended Mine at Pitfield, the Haddon and Nintingbool fruits, and the supposed termination of the Pitfield wash along a Miocene shoreline running westerly from Rokewood. The evidence of the Glenfine leaf beds has already been discussed, and it is clear that they have no bearing on the age of the superficial lavas of the

area. If, however, the sub-basaltic Pitfield wash is really coeval with the Miocene beds further south, then the basalts might conceivably be of an age not far removed from the Miocene. This, however, I would deny, for the evidence from boring shows that the Pitfield wash forms a thin sheet beneath the upper basalts, resting on a planed down bedrock surface that was undoubtedly cut by streams after the uplift of the "Oldest" drifts. These drifts have been compared with the uplifted Kalimnan and Barwonian sands and gravels in the Melbourne district, and may be littoral deposits of Miocene or Lower Pliocene age. The Pitfield wash is younger than these gravels, and Krausé has shown (1886) that the Haddon fruit-bearing leads are also younger than them. Fossil fruits have recently been obtained from the Pitfield Plains, and I regard the Pitfield wash as similar in age to the Haddon and Nintingbool fruit-bearing leads. The basalts, therefore, are Post-Miocene, and may be Pliocene or even younger.

The Geelong and Melbourne Districts.

At the Moorabool Viaduct, flows from the Anakies, which although warped along the Lovely Banks axis, are not deeply dissected (except along their western edge by the Moorabool) overlie calcareous sands, referred by Mulder (1902) to the Werrikooian. Jutson and Coulson (1937) have compared these sands with Pleistocene or Recent shell beds at Portarlington (see below), and Singleton (1935) is doubtful of their Werrikooian age, but the fauna has not been critically reviewed, and their Upper Pliocene age may be accepted for the present. Thus the Anakies flows are either very late Pliocene or younger, and as their dissection by the Moorabool indicates that they are not Recent, they may be either late Pliocene or Pleistocene. Physiographically they resemble the flows from Mt. Duneed that are overlain by Pleistocene dunes at Barwon Heads, and overlie Lower Pliocene sands (Coulson, 1938). I therefore regard them as late Pliocene or early Pleistocene. For further details concerning the Geelong district the paper by Coulson (1938) should be consulted.

In regard to the basalts of the Melbourne district, it is necessary to review the radical changes that Coulson and Jutson have suggested in the interpretations of the Melbourne Tertiaries. They argue from the supposed fact that beds at Portarlington, regarded by them as Pleistocene, grade into ferruginous sands resembling lithologically certain of the Red Beds (Hall, 1911) in the Melbourne district, that these Red Beds are therefore Pleistocene and not Barwonian and Kalimnan, as formerly believed. On this interpretation the basalts of Footscray, Essendon, and the Yarra Valley must be Middle, or, more probably, Upper Pleistocene, as they occupy valleys eroded through the Red Beds.

I have examined the sections described by these authors at the Pier and at Steele's Rock, Portarlington, and can find no evidence of the supposed merging of the calcareous and sandy beds one with the other. At the Pier it appears to me that the shell beds were artificially laid over the ferruginous series, a possibility that was noted and rejected by Jutson and Coulson. The dark, shell-bearing sands merely form a plaster on the old cliff face, and cannot be seen to pass into the sands. At Steele's Rock the shell bed is a true geological stratum, but it is only necessary to indicate the dips of the ferruginous beds on the section given by Jutson and Coulson to see that any merging of the two series is impossible. The ferruginous sands are current bedded and, also, at the eastern end of the section, warped about an axis running southwards, so that their dip is variable, but the shell bed forms a superficial layer overlying the truncated bedding planes of the red sands, on the top of the cliff. These two sections, therefore, do not necessitate any change in the accepted interpretation of the age of the Red Beds of the Geelong and Melbourne districts.

In the Melbourne district the youngest flow is that which occupies the Yarra Valley. Here, young features such as the Gardiner's Creek and Templestowe Flats, which represent alluvium deposited in lakes caused by lava barriers, are still preserved, and in its upper parts the basalt has been but slightly trenched by streams.

As shown by Kitson (1902), the marine deposits recorded beneath the creek alluvium at Forest Hill by Coates (1860) are best explicable on the hypothesis that the basalt cut off an arm of a pre-existing estuary, representing a tributary of the drowned valley of the pre-basaltic Yarra. If the drowning that produced this estuary were correlated with the post-glacial rise of sea level, then the Yarra basalt would be Recent, but its physiographic features indicate a greater antiquity than this, and it may be that the estuary was formed during an inter-glacial epoch, so that the basalt can be assigned to some part of the Pleistocene.

Since the extrusion of the Tertiary basalts of the Keilor Plains, the Maribyrnong River has cut a young valley through them. After this valley was first incised, erosion was temporarily superseded by deposition near the coast, and an alluvial filling was deposited on the valley floor, which was later entrenched, giving the paired terraces of the 40-ft. level at West Essendon and Maribyrnong. Similar paired terraces occur along the lower course of the Moonee Ponds Creek. At a later date still, the mouths of the rivers draining into Hobson's Bay were drowned, causing tidal influences to be felt for a distance of about 9 miles

up the Maribyrnong. It is clear from this sequence of events that these flows dissected by the Maribyrnong are considerably older than those which occupy the valley of the ancestral Yarra, but there is nothing to indicate whether they are Pleistocene or Pliocene. There is no doubt, however, that they are post-Kalimnan.

In regard to the age of the basalts of the Bacchus Marsh district, which overlie sands of doubtfully Upper Miocene age, containing *Cinnamomum*, a little-known paper by Brittlebank (1900) has some significance. By embedding wires of different lengths in the rocks exposed in the bed of the Werribee River, Brittlebank estimated the time that has elapsed since that river began to cut its present gorge. The results from three different stations showed a remarkable agreement, averaging 1,040,000 years. No allowance was made in this estimate for possible higher rainfall during past times or for the effects of undercutting of hard rocks underlain by soft Tertiary sands or glacial deposits, so that the estimate might possibly be more correct if the values given were halved. If this is done, the value of 520,000 years so obtained would place the date of the Rowsley fault somewhere near the beginning of the Pleistocene, so that the basalts are almost certainly Pliocene.

V. Summary and Conclusions.

In this paper the data available for the determination of the ages of the various Cainozoic volcanic rocks of Victoria have been critically reviewed. The *Cinnamomum* Flora has been shown to have a probable range in this State from Oligocene to Lower Pliocene, and the consolidated dune series, which is here correlated with the *Helicidae* Sandstones of the Bass Strait islands, is considered to range throughout the Pleistocene. Use has also been made of physiographical analogies with occurrences of known age, in dealing with the lavas of the Eastern Highlands.

Those volcanic rocks whose ages can be determined with some degree of precision fall into two groups—an Older Series, of Oligocene to Lower Miocene age, and a Newer Series, of Middle Pliocene to Recent age. It is possible that some of the flows that overlie beds containing members of the *Cinnamomum* Flora may bridge the gap between these two series, but no flow that can be dated by marine fossils or other means actually does so. Thus, the suggestion (Walcott, 1920; Edwards, 1938) that volcanic activity may have been continuous from Oligocene to Recent times, with a marked lull in the Middle and Upper Miocene and the Lower Pliocene still remains to be confirmed, and I consider it preferable, as a working hypothesis, to regard the two series as distinct.

Appendix.

Petrological Descriptions.

1. *Morass Creek.*

All the described specimens were obtained from sections along the road from Benambra to Corryong, between Uplands and the Gibbo River. Numbers in brackets refer to slides catalogued in the collection at the Department of Geology, University of Melbourne.

Olivine-iddingsite basalt [5259].—This is a highly vesicular and absolutely fresh rock with a bluish "bloom" in the vesicles. It consists of micro-phenocrysts of partially iddingsitized olivine set in a fine-grained intergranular groundmass of pale greenish-grey augite prisms, laths of basic andesine (Ab$_{56}$), and iron ore grains. Numerous minute apatite needles are included in the felspar and also in interstitial isotropic or weakly polarising colourless material, which is probably a felspathic glass.

Olivine basalt [5260, 5261].—These are non-vesicular but porous rocks, rather coarser in grain than the vesicular type. They contain micro-phenocrysts of unaltered olivine set in an intergranular groundmass of pale green and greyish augite with pale violet and greyish violet titan-augite, olivine granules, and plagioclase laths, some of which are zoned from a central core of andesine-labradorite (Ab$_{50}$) to an outer rim of oligoclase (Ab$_{80}$). Interstitial yellow-green serpentine [5262], rare iddingsite [5261], apatite needles, granules and plates of iron ores, and turbid glass are also present. A "pipe vesicle" [5258], contains fewer olivine phenocrysts than the average rock, and has larger felspar laths, which are shot through with long apatite needles. Rare xenocrysts of quartz in [5262] and [5263] are surrounded by rims of green augite, and in [5263] the texture is much coarser than usual, in the neighbourhood of the quartz inclusions. There, large skeletal crystals of pale green augite are associated with dendritic platy steel-grey iron ores, and large plagioclase grains. Near the xenocrysts the olivine is iddingsitized, and interstitial brown glass, calcite, and radial aragonite occur.

2. *Gelantipy.*

Most of the described specimens were collected from sections along the Buchan-Woolgulmerang Road. Numbers in parenthesis indicate distances in yards either north (N) or south (S) of the most northerly bridge over Butcher's Creek, about 3 miles south of Gelantipy. Other specimens were obtained from a natural section along Butcher's Creek about a mile north of this bridge.

Porphyritic olivine basalt (1862 S.) [5271].—This is a dense rock containing acicular glassy phenocrysts of plagioclase up to about 5 mm. long, a few amygdales of calcite, and rare turbid phenocrysts of anorthoclase. The plagioclase phenocrysts are labradorite Ab$_{35}$, and are twinned on the Carlsbad, albite, and pericline laws. A few partially serpentinized micro-phenocrysts of olivine are present, and the groundmass consists of an intergranular aggregate of colourless augite prisms, iron ore grains, and plates and laths of andesine-labradorite, Ab$_{50}$. Green and smoke-grey glass, the latter full of minute specks of iron ores, fill the interstices, together with a few small apatite needles. The anorthoclase phenocrysts are each composed of an aggregate of distinct individuals, which have evidently passed through a stage when they were not in equilibrium with the magma, as their cores are spongy, containing numerous small inclusions of augite and iron ore grains.

Olivine basalts.—The other basalts from this district are not macroscopically porphyritic, and most of them are dense and fine-grained, containing a few amygdales of calcite. They contain micro-phenocrysts of fresh olivine (550 N. [5267]) or pseudomorphs of serpentine after olivine

(2556 S. [5269]; 3033 S. [5264]) set in an intergranular groundmass of colourless augite granules, basic andesine (Ab_{60-65}) laths, and iron ores. In [5264], which is tachylitic, the mesostasis is a black glass full of specks of black iron ores, and the usual granular or platy iron ores are absent from this rock. In [5267] the glassy mesostasis is pale green, and in [5266] (713 N.) both black and green glass occurs.

[5265] (519 N.) is a vesicular and porous type, similar to the others except that it contains a red to red-brown mineral which is probably iddingsite, although in part it appears to have crystallized directly from the magma, as it has in places a banded colloform structure. A colourless isotropic mineral, of low refractive index, occurs as well defined interstitial grains. This is probably analcite.

The specimens from Butcher's Creek are both olivine basalts, but are richer in olivine than those above described, this mineral occurring both as micro-phenocrysts and as granules in the groundmass. The latter contains prisms of pale green and colourless augite, iron ore grains, and laths of basic andesine (Ab_{55}). In [5268], which is the lower flow at this point, green and yellow-green glass occurs in the mesostasis, while in the upper flow, [5270], the glass is black.

Throughout all the slides interstitial calcite is common, and minute apatite needles and rods occur in the felspars and the mesostasis.

3. *South Buchan.*

All the specimens were collected from a low hill on the west of the South Buchan-road, about 4 miles south of Buchan. Slides [5273-5276] are serpentinized olivine basalts, in which serpentine occurs both as pseudomorphs after olivine and as interstitial patches. The pyroxene is either green or a pale violet titanaugite, and the plagioclase basic labradorite, Ab_{35}. Black glass containing specks of iron ores is common.

No. [5272] is a dense black rock consisting entirely of small iddingsite granules, plagioclase laths (basic labradorite), interstitial pale green serpentine, and black glass, the latter being practically opaque, owing to the crowding of minute specks of iron ore within it.

4. *Seven Creeks, Euroa.*

[5277], from a stony knoll east of the confluence of Wombat Creek and Seven Creeks, and [5278], from the east side of Seven Creeks, about 2 miles downstream from the above, are both limburgitic basalts containing numerous phenocrysts of olivine, marginally iddingsitized, set in a fine-grained intergranular to sub-ophitic groundmass consisting of rods of colourless augite with much interstitial turbid glass and a few ill-defined large plagioclase laths. Large grains of black iron ores are plentiful. [5279], from a hill on the west side of Seven Creeks, in Allotment 27, Gooram Gooram Gong, is a true limburgite consisting of phenocrysts of unaltered olivine and colourless augite, some grains of which, however, have purple margins which are titaniferous. These are set in a dense groundmass consisting of augite rods with interstitial black glass. [5278] is a vesicular type; the others are dense.

REMARKS.

Comparing the above lavas with the petrological types established by Edwards (1938), it will be noted that characteristic Older Volcanic types such as crinanites, ophitic titanaugite dolerites, and nephelinites are absent. The porphyritic olivine-poor basalt from Gelantipy appears to be tholeiitic in nature, although it cannot be established under the microscope that the pyroxenes are pigeonitic, as the grains are too small to enable 2V to be determined.

Iddingsite occurs in both Newer and Older Volcanic rocks, and its presence at all the above localities therefore has little significance. Nevertheless, this mineral is commoner in Newer Volcanic rocks than in Older.

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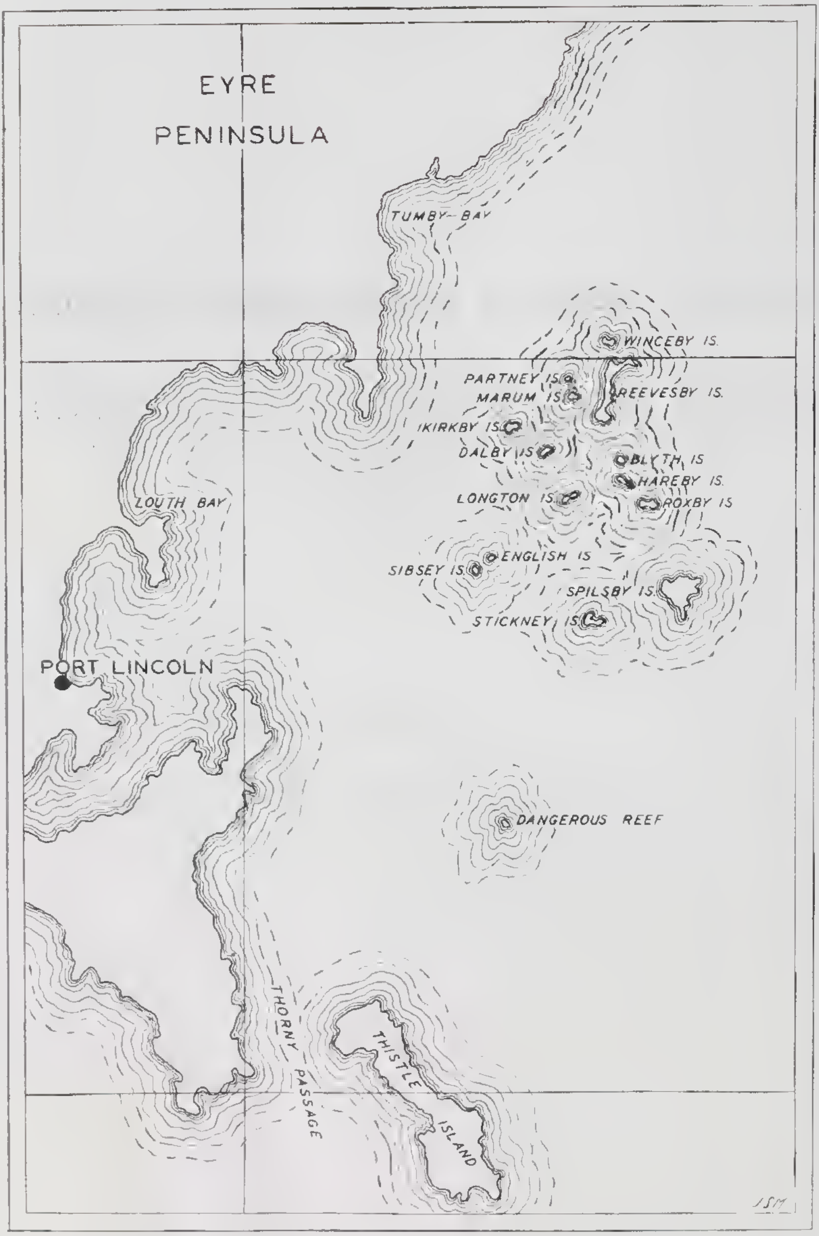
ART. VIII.—THE SIR JOSEPH BANKS ISLANDS.

REPORTS OF THE EXPEDITION OF THE McCOY SOCIETY FOR FIELD INVESTIGATION AND RESEARCH.

PART TWO.

Contents.

1. Geology.—Irene E. Dewhurst.
2. Survey of the Vegetation Community on Reevesby Island.—R. H. Hayman and E. E. Henty.
3. Lichens.—Ethel M. Shackell.
4. Mollusca Part 2: General.—B. Cotton.
5. Pisces.—J. S. Guest and D. B. Robertson.



The Sir Joseph Banks Islands.

1. *Geology.*

By IRENE E. DEWHURST, B.Sc.

The islands of the Sir Joseph Banks Group are part of Fenner's Spencer-Vincent Sunkland, and have the same geological history as the neighbouring mainland. The islands consist of ancient granites and gneisses capped by travertine and blown sands. Throughout the group the islands are small and low, the highest points being 162 feet on Spilsby, and 91 feet on Reevesby. Most of the following geological notes were made on Reevesby Island.

Reevesby Island originally consisted of three separate islets, which are now connected by sand dunes. Owing to the arid climate and the porous surface deposits no valleys have been cut by streams, and the physiography of the group is governed by the action of wind and waves.

The principal land-forms are sand-dunes and sandy plains. Sand-dunes extend along almost the whole east coast from McCoy Bay to Haystack Bay, but are less continuous on the west coast; low sand-hills practically surround the sand plain on which the camp was situated and form parallel ridges behind the coastal sand-dunes. Except where bound by vegetation, the dunes, particularly the dunes forming the ties, are shifting. Some sand-hills, such as the hill of 60 feet towards the north end of Reevesby Island, are more permanent. The physiography of the other islands is, in general, dominated by blown sand; high sand-hills completely encircle Blyth Island, leaving a sandy hollow in the middle.

Towards the south end of Reevesby are two salt pans occupying areas to which, at one time, the sea had access and deposited salt.

The coastline of the north and south ends of Reevesby Island, is low and rugged; elsewhere are open shallow bays, with long beaches and small projecting headlands or reefs.

Where granites and gneisses outcrop at sea-level, two sets of joints favour the formation of tors and boulders.

Travertine outcropping at sea-level is undercut by the waves, and pot holes and small storm caves are common in this rock.

Low reefs of lateritic ironstone some 7 or 8 square chains in area occur on the west coast of the south end of Reevesby Island, and also off Roxby Island.

The coast is shelving, and at low tide the sea recedes 20 or 30 yards. On the west coast of Reevesby, a sand spit extending south-westerly from Middle Rocks has been formed by currents sweeping sands from the north. Moreton Bay is fast being silted up.

The following series of formations is found:—

1. *Recent Sands.*—Coastal dunes and loose sands extending inland, formed of granitic detritus and comminuted shells.

2. *Older Sand-hills.*—Friable dune rock formed by consolidation of similar sands. Recent shells, very little altered, were found in a small excavation in this rock near the camp.

3. *Travertine.*—More or less massive limestone, fairly pure to coarse and sandy; bedded, concretionary or nodular; it generally rests immediately upon the ancient granite-gneiss complex. A cliff 15 to 20 feet high at the south end of Reevesby Island gives the following section:—

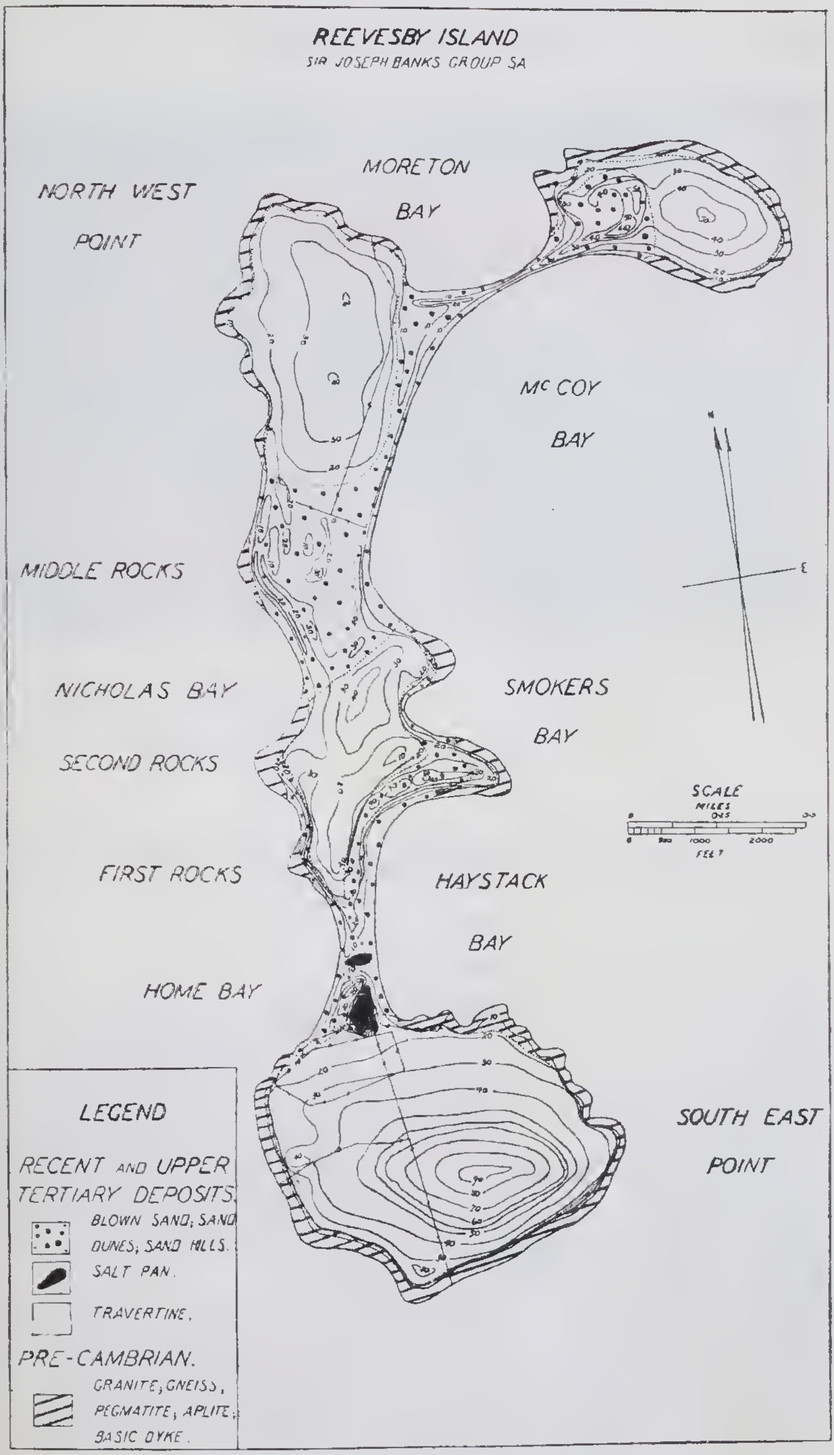
(i) Red clay with buckshot, 3 feet (base).
(ii) Impure reddish travertine passing up to white, nodular travertine, 7 feet.
(iii) Sandy travertine, 3 feet.
(iv) Red travertine soil, 2 feet (top).

The section apparently represents two phases: the first (i, ii) followed after an interval by a second (iii, iv).

4. *Lateritic Ironstone.*—Thin beds exposed as reefs at low tide. They rest immediately on granitic rocks, from which they have been formed by weathering. The lateritic ironstone consists of felspar (5 per cent.), biotite (10 per cent.), limonite and haematite (20–30 per cent.), cliachite (50 per cent.) in about the proportions shown, and is associated with bauxite and common ironstone. Elsewhere it is replaced by ferruginous grit consisting of siliceous grains cemented by iron oxide.

5. *The Pre-Cambrian Complex.*—The granite-gneiss complex seldom outcrops except on the coast. The rock types are:—

(i) *Norite.*—Forms dark-coloured dense "basic dykes" and patches in the granites. The rock consists of plagioclase, a little orthoclase, pyroxenes (hypersthene and a little diopside) biotite, accessory augite, magnetite and ilmenite.
(ii) *Pegmatite and Aplite.*—Plentiful dykes, veins and tongues. Some pegmatites are extremely coarse grained mixtures of massive pink felspar and blue to white quartz. The aplites, usually pink are fine, even grained, saccharoid rocks consisting of quartz, plagioclase (sericitized), minor orthoclase, microcline, myrmekite, muscovite, biotite (chloritized), with a little magnetite and ilmenite altering to leucoxene. Occasionally mortar structure has been developed.
(iii) *Granites.*—Coarse-grained throughout, red or grey in colour, frequently gneissic. The gneissic types are generally porphyritic.



Geology of Reevesby Is.—Field work by Alan Gordon and Irene E. Dewhurst.

(iv) *Acid Gneisses*:—

(*a*) Augen Gneiss.—Very abundant. The augens are mainly of felspar. The rock consists of quartz with undulose extinction, felspars (microcline, les abundant orthoclase, microperthite and oligoclase), biotite (with inclusions of apatite and zircon), magnetite (altered to haematite), ilmenite (altered to leucoxene). Quartz and orthoclase form symplektitic intergrowths, and the oligoclase contains vermicular inclusions of quartz.

(*b*) Biotite-Granite Gneiss.—A normal type composed of felspar, quartz, and biotite.

(*c*) Granulite.—Less common. An even-grained, granular rock consisting of hornblende, hypersthene, less abundant biotite, quartz, plagioclase, and small grains of ilmenite.

(v) *Basic Gneiss*.—A dark-grey amphibolite, sometimes schistose, occurring both in irregular patches and in definite bands in the acid gneisses. The bands have their longer axes parallel to the foliation in the gneiss (Pl. 8, f. 1).

Wade and others consider that these gneisses represent metamorphosed limestones.

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Explanation of Plates.

Fig. 1. Relationship of Acid gneiss (g), norite (n), aplite (ap.) and amphibolite (a).

Fig. 2.—Channel formed by weathered "basic dyke".

Fig. 1.

Fig. 2.

2. *Survey of the Vegetation Community on Reevesby Island.*

By R. H. HAYMAN, B.Agr. Sc. and E. E. HENTY, B.Agr. Sc.

The survey was made over a period of three weeks in January, 1937. The accompanying map shows the main vegetation communities observed during that time. It was noted that each community was largely confined to its own soil type; the map could therefore be used as a rough soil map also.

The soils are predominantly sandy in character, varying from a shallow red sandy loam over travertine limestone at a depth of 3-6 inches to a white sandy loam over travertine, or deep white sand on the dunes.

The vegetation of the island is divided into four communities:—

1. The saltbush plain.
2. The *Myoporum-Olearia* community.
3. The sand dunes.
4. The salt pans.

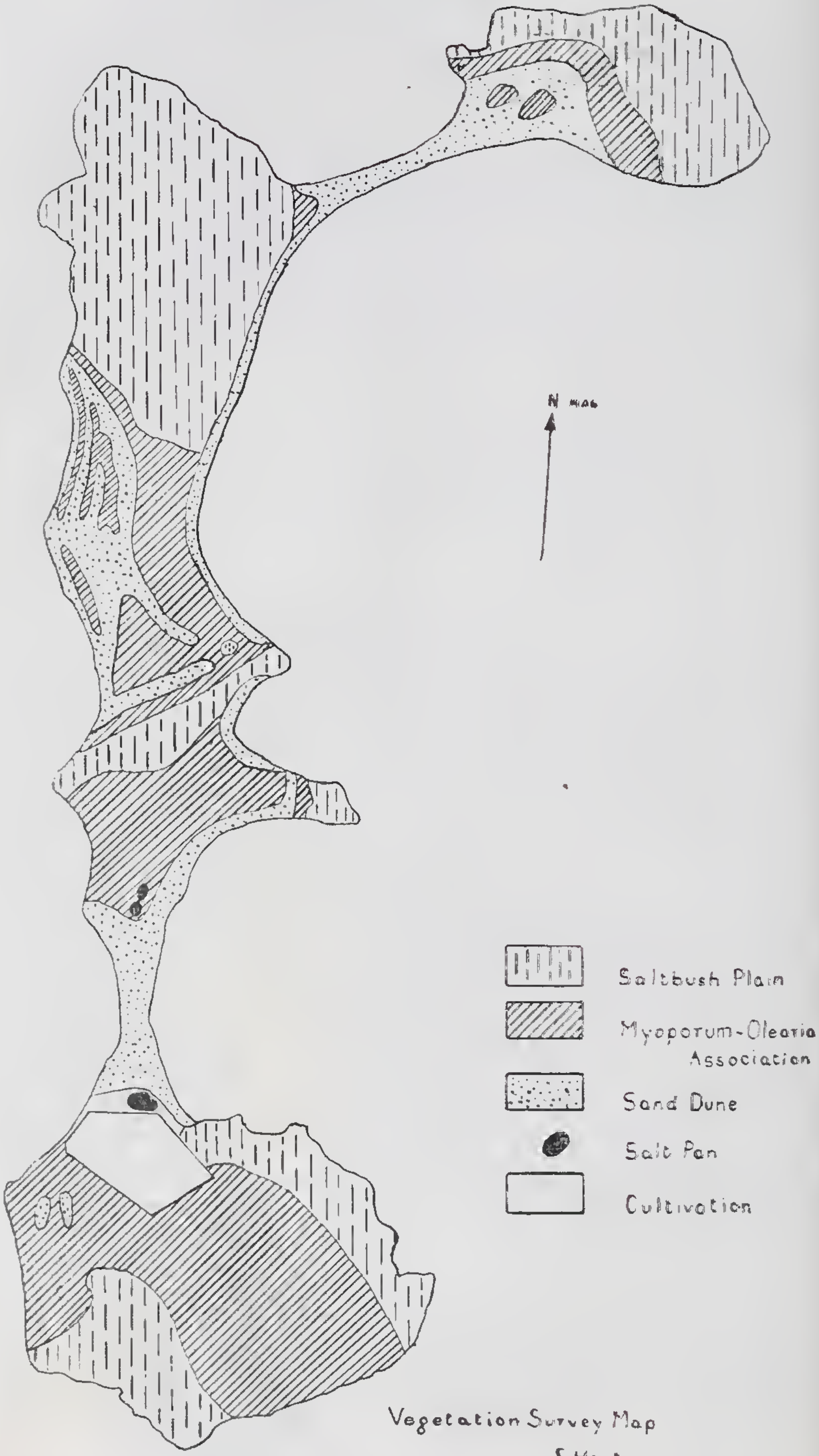
1. The Saltbush Plain.

This occupies about one-third of the area of the island, chiefly towards the northern end, and is typical of the shallow red sandy soils. The dominant plant is *Atriplex paludosum*, which grows in roughly circular patches ranging in diameter from 4-10 feet. In many cases the centres of the patches are dead, leaving an annulus of green material; this is possibly due to the grazing and trampling of sheep which are kept on the island. *Atriplex Muelleri* and *Rhagodia crassifolia* occur to some extent; *Lycium australe* is a feature of the higher and more barren parts of the community; and stunted bushes of *Myoporum insulare* are scattered throughout the area. All the shrubs are fairly well separated, giving an open community. Grasses and herbaceous annual plants are little in evidence at this time of the year, except *Pelargonium australe*, which is widespread. The only grasses still green at this time are *Festuca rigida, Lepturus incurvatus, Danthonia semi-annularis* and *Stipa scabra*. Residues of many other grasses, including *Hordeum murinum, Festuca bromoides, Koeleria phleoides* and several species of Stipas, are also present, indicating an abundant gramineous flora during the rainy season. *Mesembrianthemum australe* is widespread, and *M. crystallinum* is also present where the original saltbush has been destroyed. Burrs of *Medicago denticulata* are also common.

2. The Myoporum-*Olearia* community.

Olearia axillaris is dominant and *Calocephalus Brownii* subdominant on the small plains along the sand dunes on the west side of the island. On the deep soil near the dunes and on the fringe of the saltbush plains *Myoporum insulare* becomes

REEVESBY ISLAND



dominant, though in the latter place the shrubs are very stunted. The distribution of the *Olearia* is apparently affected by the depth of the soil, and its range is more limited than *Myoporum,* as it is absent where the soil is shallow along the edge of the saltbush plain, and also where the soil deepens along the edge of the sand dunes, *Myoporum* assuming the dominance in each case.

In the complex the *Myoporum* grows to a height of about 12 feet and is generally covered by the trailing *Muehlenbeckia adpressa* which is a feature of the community. *Olearia axillaris* and *O. ramulosa* grow to a height of 5-7 feet. Two stunted trees of *Casuarina stricta,* five specimens of *Eucalyptus angulosum* and several specimens of *Acacia rupicola* are present. This is by far the tallest association on the island.

3. The Sand Dunes.

Sand dunes occur along most of the eastern foreshore, in the west central part of the island, and on the two narrow necks to the north and south of the island.

Vegetation on the dunes is very scattered; *Myoporum insulare* is the main plant, and *Muehlenbeckia adpressa* accompanies it. In several places *Atriplex cinereum* is present as large shrubs. *Spinifex hirsutus* is present in isolated patches, and *Ammophila arenaria* and *Lolium rigidum* are also to be found.

The dunes along the east coast show signs of moving inland; along their inner edges are clear indications that the scrub is being covered over (Pl. IX., fig. 1).

4. The Salt Pans.

The vegetation is here composed mainly of *Suaeda australis* and *Arthrocnemum halocnemoides* var. *pergranulatum,* interspersed with large areas of vacant ground. The pans consist of an impermeable layer of clay and are flooded after rain. Salt crystals occur on the surface.

General.

The climate of the island is semi-arid with winter rain. The rainfall of the adjacent mainland is 15 inches approximately, and the 15-in. isohyet passes through the group of islands. The perennial plants are either xerophytic or succulent, while the annuals are true mesophytes with a winter growing period, maturing before the summer drought sets in.

Variation in the vegetation seems to be due almost entirely to edaphic factors, the climate being uniform over such a small area, while aspect, as a factor, is largely eliminated by the flat nature of the island.

Atriplex paludosum grows only on the shallow red sandy soil; *Myoporum insulare* on all soils, but less effectively on the shallow soil; *Olearia axillaris* is restricted to those areas where there is only about 12 inches of soil above the travertine; and *Atriplex cinereum* to the deep sand.

Explanation of Plates.

PLATE IX.

Fig. 1.—Typical *Myoporum-Olearia* community. In the left foreground a sand dune is seen moving inland and covering an *Olearia* shrub.

Fig. 2.—Small plain among sand dunes, showing the dominance of the *Olearia*.

PLATE X.

Fig. 1.—Typical sand dunes and their vegetation.

Fig. 2.—Typical salt pan; *Myoporum-Olearia* community in the foreground, sand dunes in the rear.

Fig. 1.

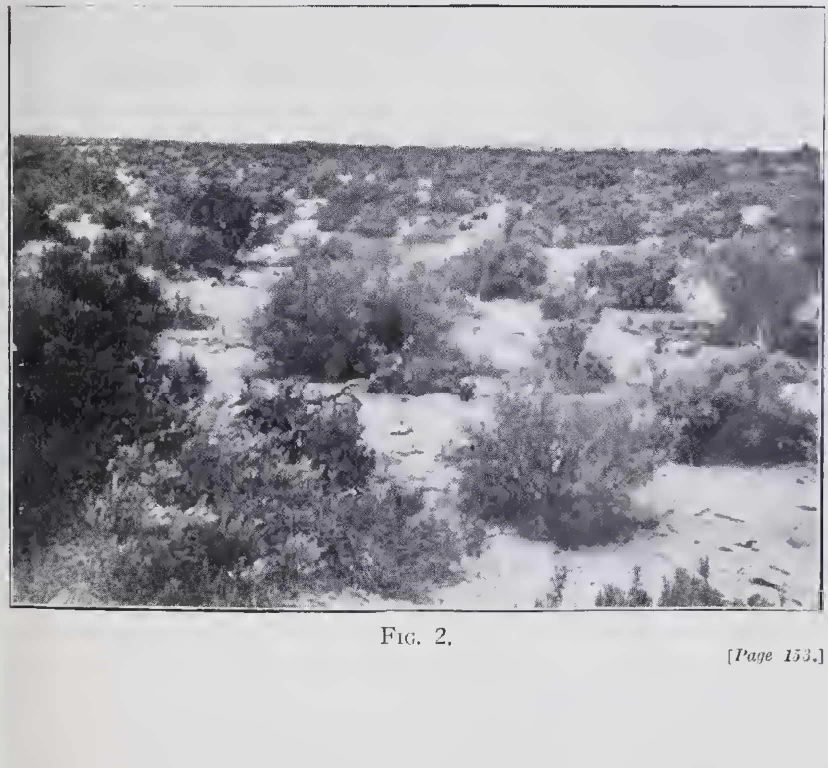


Fig. 2.

Fig. 1.

Fig. 2.

[Page 155.]

3. *Lichens.*

By ETHEL M. SHACKELL, M.Sc.

All forms collected are well known Southern Australian species. They occurred commonly on the rocks around the sea fronts of the islands, some spreading inland on rocks or dead wood. Two species are confined to inland localities where they were found on Austral Box Thorn (*Lycium australe*). Weathering of the crustaceous species was pronounced on the exposed rock surfaces, the older central regions of the thallus being disintegrated by repeated swelling and contracting of the deeply areolated plant body in response to alternating wet and dry conditions. Particles of the thallus thus become easily dislodged, leaving bare places in the centre of the thallus. These patches may become recolonized in time, either by the same lichen or by an invading species.

The classification follows Fink (The Lichen Flora of the United States, 1935, pp. 1-426).

Class ASCOLICHENES.

Subclass GYMNOCARPEAE.

Order CALICIALES.

Family CALICIACEAE.

MYCOCALICIUM PARIETINUM (Acharius, 1816).

Calicium parietinum Ach., Kgl. Vetensk.-Akad. Nya. Handl. 1816, p. 260, pl. 8, f. 1 a-b.

Mycocalicium parietinum (Ach.), Wainio, Etud. Lich. Bres., II., 1890, p. 182.

On dead wood at Reevesby Island.

Order LECANORALES.

Family PERTUSARIACEAE.

PERTUSARIA NOLENS Nylander, 1864.

Pertusaria nolens Nyl., Flora XLVII., 1864, p. 489.

On granitic rocks at Winceby, Langdon, Kirkby, Reevesby, Hareby, Marram, and Stickney Islands.

Family PARMELIACEAE.

PARMELIA LIMBATA (Laurer, 1833).

Parmelia limbata (Laur.) Shirley, Lichen Flora of Queensland, 1890, p. 46.

On granitic rocks and dead wood at Langdon, Reevesby, and Stickney Islands.

Family USNEACEAE.

Ramalina fraxinea (Linn., 1753).

Lichen fraxineus Linn. Species Plantarum, 1753, pp. 1146, 1147.

Ramalina fraxinea (Linn.), Ach., Lichenographia Universalis, 1810, p. 122, pl. 13, f. 5-11.

On *Lycium australe* at Reevesby Island.

Family TELOSCHISTACEAE.

Teloschistes villosus (Acharius, 1803).

Parmelia villosa Ach., Meth. Lich., 1803, p. 254.

Teloschistes villosus (Ach.), Norman, Nyt. Mag. Naturv., VII., 1852, p. 229.

On *Lycium australe* at Reevesby Island.

Teloschistes polycarpus (Ehrhart, 1798).

Lichen polycarpus Ehrh., in Ach. Lich. Suec., 1798, p. 135.

Teloschistes polycarpus (Ehrh.), Tuckerman, Syn. N. A. Lich., I., 1882, p. 50.

On granitic rocks and wood at Winceby, Langdon, Kirkby, Reevesby, Hareby, Marram, Little English, and Stickney Islands.

4. *Mollusca, Part 2; General.*

By BERNARD C. COTTON, South Australian Museum.

During December 1936, by invitation of the McCoy Society, the author visited the Banks Group, Spencer Gulf, and collected Mollusca. Part I. of this paper (Proc. Roy. Soc. Vic. I. (n.s.) pt. II. 1938) describes the spermatophore of *Rossia australis* Berry from specimens taken at Reevesby Island; the present paper, Part II., gives a list of species obtained, erects one new genus, one new subgenus, and describes eight new species.

Localities are indicated as follows:—Loc. 1, Reevesby Island, west beach; Loc. 2, Reevesby Island, north beach; Loc. 3, Reevesby Island, east beach; Loc. 4, Reevesby Island, south beach; Loc. 5, Lusby Island; Loc. 6, English Island; Loc. 7, Winceby Island.

Class PELECYPODA.

Family SOLEMYIDAE.

SOLEMYA AUSTRALIS Lamarck, 1818.

Solemya australis Lamk., Anim. S. Vert., V., 1818, p. 489.

Loc. 1; two specimens.

Family ARCIDAE.

BARBATIA PISTACHIA (Lamarck, 1819).

Arca pistachia Lamk., Anim. S. Vert., VI., 1819, p. 41.
Barbatia pistachia (Lamk.). Cotton, Rec. S. Aust. Mus., IV., 2, 1930, p. 228

Loc. 1; numerous.

BARBATIA LAMINATA (Angas, 1865).

Arca laminata Angas, P.Z.S., 1865, p. 655.
Barbatia laminata (Angas), Cotton, Rec. S. Aust. Mus., IV., 2, 1930, p. 228.

Loc. 1; one specimen dredged alive in three fathoms.

Family LIMOPSIDAE.

LIMOPSIS FORTERADIATUS Cotton, 1930.

Limopsis tenisoni forteradiatus Cotton, Rec. S. Aust. Mus., IV., 2, 1930, p. 231.

Loc. 1, 2; two dead specimens, probably subfossil. Fairly common on South Australian raised beaches; less common on ordinary beaches but abundant at 10 fathoms.

Family GLYCYMERIDAE.

GLYCYMERIS RADIANS (Lamarck, 1819).

Pectunculus radians Lamk., Anim. S. Vert., VI., 1819, p. 54.

Loc. 1; twelve specimens.

Family VULSELLIDAE.

MALLEUS MERIDIANUS Cotton, 1930.

Malleus meridianus Cotton, Rec. S. Aust. Mus., IV., 2, 1930, p. 232.

Loc. 1, 2, 3, 4; numerous.

Family PTERIIDAE.

ELECTROMA GEORGIANA (Quoy & Gaimard, 1835).

Avicula georgiana Q and G., Voy. de L'Astrol, III., 1835, p. 457, pl. 77, f. 10, 11.

Loc. 1, 2; numerous.

Family PINNIDAE.

PINNA DOLABRATA Lamarck, 1819.

Pinna dolabrata Lamk., Anim. S. Vert., VI., 1819, p. 133.

Loc. 1, 3; numerous at low tide mark, with chitons attached.

Family OSTREIDAE.

OSTREA SINUATA Lamarck, 1819.

Ostrea sinuata Lamk., Anim. S. Vert., VI., 1819, p. 208.

Loc. 1, 2, 3; odd dead specimens.

Family TRIGONIIDAE.

NEOTRIGONIA BEDNALLI (Verco, 1907).

Trigonia bednalli Verco, Tr. R. Soc. S. Aust., XXXI., 1907, p. 213, pl. 28, f. 1-3.

Loc. 1; two eroded valves.

Family PECTINIDAE.

NOTOVOLA ALBA (Tate, 1887).

Pecten fumatus albus Tate, Pr. R. Soc. Tasm., 1887, p. 113.

Loc. 1, 2.

EQUICHLAMYS BIFRONS (Lamarck, 1819).

Pecten bifrons Lamk., Anim. S. Vert., VI., 1819, p. 164.

Loc. 1, 2, 6.

Scaeochlamys aktinos (Petterd, 1885).

Chlamys aktinos, Pett., Pr. Roy. Soc. Tasm., 1885, p. 320.

Loc. 1; one specimen.

Mimachlamys asperrimus (Lamarck, 1819).

Pecten asperrimus Lamk., Anim. S. Vert., VI., 1819, p. 174.

Loc. 1, 2, 3, 4, 5, 6.

Family SPONDYLIDAE.

Spondylus tenellus Reeve, 1856.

Spondylus tenellus Reeve, Conch. Icon., IX., 1856, pl. 18, f. 67.

Loc. 1, 2, 3; numerous, up to 75 mm. in diameter.

Family LIMIDAE.

Australima gemina Iredale, 1929.

Australima nimbifer gemina Ird., Rec. Aust. Mus., XVII., 4, 1929, p. 165.

Loc. 1; two specimens.

Mantellum orientale (Adams & Reeve, 1850).

Lima orientalis A. & R., Zool. Samarang, 1850, p. 75, pl. 11, f. 33.

Loc. 1.

Limatula strangei (Sowerby, 1872).

Lima strangei Sow., Conch. Icon., XVIII., 1872, pl. III., f. 15.

Loc. 1; one specimen.

Family ANOMIIDAE.

Monia ione (Gray, 1850).

Placuanomia ione Gray, P.Z.S., 1850, p. 123.

Loc. 1, 3.

Family MYTILIDAE.

Modiolus areolatus Gould, 1850.

Modiolus areolatus Gould, Pr. Boston Soc. Nat. Hist., III., 1850, p. 343.

Loc. 1, 2, 3.

Brachyodontes erosus (Lamarck, 1819).

Mytilus erosus Lamk., Anim. S. Vert., VI., 1819, p. 120.

Loc. 1, 2, 3, 4; a bed of these mussels is situated off the S.W. coast of Reevesby Island; depth one fathom.

BRACHYODONTES HIRSUTUS (Lamarck, 1819).

Mytilus hirsutus Lamk., Anim. S. Vert., VI., 1819, p. 120.

Loc. 1, 2, 3, 6.

MUSCULUS NANUS (Dunker, 1856).

Lanistina nanus Dunk., P.Z.S., 1856, p. 365.

Loc. 1; two examples.

Family CLEIDOTHAERIDAE.

CLEIDOTHAERUS ALBIDUS (Lamarck, 1819).

Chama albida Lamk., Anim. S. Vert., VI., 1819, p. 96.

Loc. 1, 3.

Family CLAVAGELLIDAE.

CLAVAGELLA MULTANGULARIS (Tate, 1886).

Aspergillum multangularis Tate, Pr. R. Soc. S. Aust., 1886, p. 64.

Loc. 1; four examples.

Family CRASSATELLIDAE.

EUCRASSATELLA VERCONIS Iredale, 1936.

Eucrassatella kingicola verconis Ird., Rec. Aust. Mus., Vol. XIX., 5, 1936, p. 271.

Loc. 1, 2, 3, 4.

Family CARDITIDAE.

CARDITA CRASSICOSTATA Lamarck, 1819.

Cardita crassicostata Lamk., Anim. S. Vert. VI., 1819, p. 24.

Loc. 1; rather common, large.

Family CHAMIDAE.

CHAMA RUDERALIS Lamarck, 1819.

Chama ruderalis Lamk., Anim. S. Vert., VI., p. 96, 1819.

Loc. 1; two specimens.

Family LEPTONIDAE.

EPHIPPODONTA MACDOUGALLI Tate, 1888.

Ephippodonta macdougalli Tate, Tr. R. Soc. S. Aust., XI., 1888, p. 64, pl. XI., f. 5*a-b*.

Loc. 3; under large stones on reef at low tide; one alive. Not previously recorded from Spencer Gulf. A series from Port Lincoln show obscure secondary concentric sculpture which bridges the radials. One specimen is bright pink.

EPHIPPODONTA LUNATA (Tate, 1886).

Scintilla (?) *lunata* Tate, Tr. R. Soc. S. Aust., IX., 1886, p. 69, pl. IV., f. 8.

Loc. 3; under large stones on reef at low tide. The granose sculpture separates from the shell very easily, leaving a smooth surface. Some examples differ from the typical *lunata* in being consistently smooth and more solid, and in having a smaller, sharper umbo and well defined brown radial flames. One specimen is bright pink.

Family CARDIIDAE.

CARDIUM RACKETTI Donovan, 1826.

Cardium racketti Don., Nat. Repository, IV., 1826, p. 125.

Loc. 1, 4; specimens from Loc. 1 measure up to 46 mm. in height.

CARDIUM ERUGATUM Tate, 1888.

Cardium erugatum Tate, Tr. R. Soc. S. Aust., XI., 1888, p. 62, pl. XI., f. 6.

Loc. 1, 4; one specimen from each locality. Hitherto taken only from Southern York Peninsula.

Family VENERIDAE.

CALLANAITIS DISJECTA (Perry, 1811).

Venus disjecta Perry, Conchology, pl. 58, f. 3, 1811

Loc. 1; three odd valves.

TAWERA GALLINULA (Lamarck, 1818).

Venus gallinula Lamk., Anim. S. Vert., V., 1818, p. 592.

Loc. 1, 3; numerous, large.

KATELYSIA SCALARINA (Lamarck, 1818).

Venus scalarina Lamk., Anim. S. Vert., V., 1818, p. 508.
Katelysia corrugata (Lamk.), Cotton, Rec. S. Aust. Mus., V., 1934, p. 173.

Loc. 2; numerous, small.

VENERUPIS GALACTITES (Lamarck, 1818).

Venus galactites Lamk., Anim. S. Vert., V., 1818, p. 599.

Loc. 1; apparently the dominant bivalve in this locality.

Family TELLINIDAE.

PSEUDARCOPAGIA VICTORIAE Gatliff & Gabriel, 1914.

Pseudarcopagia victoriae G. and G., Vict. Nat. XXXI., 5, 1914, p. 83.

Loc. 1; one specimen.

Family PSAMMOBIIDAE.

PSAMMOBIA LIVIDA Lamarck, 1818.

Psammobia livida Lamk., Anim. S. Vert., V., 1818, p. 515.

Loc. 1; four specimens.

SOLETELLINA BIRADIATA (Wood, 1815).

Solen biradiata Wood, General Conch., 1815, p. 135, pl. 33, f. 1.

Loc. 1, 2; at Loc. 2, on sand flats and about 16 inches below surface, alive.

Family MACTRIDAE.

MACTRA PURA Deshayes, 1853.

Mactra pura Desh., P.Z.S., 1853, p. 15.

Mactra (Telemactra) abbreviata Lamk., Cotton, Rec. S. Aust. Mus., V., 1934, p. 176.

Loc. 1; numerous, large.

MACTRA AUSTRALIS Lamarck, 1818.

Mactra australis Lamk., Anim. S. Vert., V., 1818, p. 475.

Loc. 1; four specimens.

ANAPELLA PINGUIS (Crosse & Fischer, 1864).

Mactra pinguis, C. and F., J. de Conch., XII., 1864, p. 349.

Anapella cycladea Lamk., Cotton, Rec. S. Aust. Mus., V., 1934. p. 176.

Loc. 1; one specimen.

LUTRARIA RHYNCHAENA Jonas, 1844.

Lutraria rhynchaena Jonas, Zeit. f. Malak., 1., 1884, p. 34.

Loc. 1, 2, 4.

Family AMPHIDESMATIDAE.

AMPHIDESMA CUNEATA (Lamarck, 1818).

Crassatella cuneata Lamk., Anim. S. Vert., V., 1818, p. 843.

Class CEPHALOPODA.

Family SPIRULIDAE.

SPIRULA SPIRULA (Linne, 1758).

Nautilus spirula Linne, Syst. Nat., ed. X., 1758, p. 710.

Loc. 1; three specimens.

Family SEPIIDAE.

MESEMBRISEPIA CHIROTREMA (Berry, 1918).

Sepia chirotrema Berry, "Endeavour" Biol. Res., IV., 1918, p. 268, pl. LXXIV., f. 3-9, pl. LXXV.-LXXVII.

Loc. 1; two fragments.

MESEMBRISEPIA NOVAEHOLLANDIAE (Hoyle, 1909).

Sepia novae, hollandiae Hoyle, Pr. R. Phys. Soc. Edin. XVII., 1909, p. 266.

Loc. 1, 2, 3, 4; numerous.

ARCTOSEPIA BRAGGI (Verco, 1907).

Sepia braggi Verco, Tr. R. Soc. S. Aust., XXI., 1907, p. 213, pl. XXVII., f. 6 a-d.

Loc. 1; four specimens. First record for Spencer Gulf.

AMPLISEPIA APAMA (Gray, 1849).

Sepia apama Gray, Cat. Moll. Brit. Mus. (Cephalopoda), 1849, p. 103.

Loc. 1, 2, 3, 4; fairly numerous.

Family ARGONAUTIDAE.

ARGONAUTA NODOSA Solander, 1786.

Argonauta nodosa Solander, Portland Cat., 1786, p. 76.

Loc. 2.

Family SEPIOLIDAE.

ROSSIA AUSTRALIS Berry, 1918.

Rossia australis Berry, "Endeavour" Biol. Res., IV., 1918, p. 253, pl. XIX., f. 3, 4, pl. LXX.

Loc. 1; two juvenile females and one male taken at a depth of 4 feet over a mussel (*B. erosus*) bed. Spermataphore described in previous part of this report.

Family OCTOPODIDAE.

OCTOPUS AUSTRALIS Hoyle, 1885.

Octopus australis Hoyle, Ann. Mag. Nat. Hist. (5), V., 1885, p. 224.

Loc. 1; four females netted in shallow water. The central area of the dorsal surface is edged with white and has a narrow, light brown strip on either side; specimens from Gulf St. Vincent have a uniformly brown dorsal surface. Ventral surface yellowish white; arms light brown on outer, yellowish white on inner surface; body and outer base of arms fairly granular.

Family LOLIGINIDAE.

SEPIOTEUTHIS AUSTRALIS Quoy & Gaimard, 1824.

Sepioteuthis australis Q. and G., Voy. de L'Astrolabe, Zool. II., 1832, p. 77, pl. IV., f. 1.

Loc. 1, 2, 3, 4, 5, 6, 7; plentiful.

Class LORICATA.

Family ISCHNOCHITONIDAE.

ISCHNOCHITON LINEOLATUS (Blainville, 1825).

Chiton lineolatus Bl., Dict. Sci. Nat., XXXVI., 1825, p. 541.

Loc. 1, 3; numerous specimens under weed-covered rocks at extreme low tide.

ISCHNOCHITON VARIEGATUS (Adams & Angas, 1864).

Lepidopleurus variegatus A. and A., P.Z.S., 1864, p. 192.

Loc. 1. 3; numerous on rocks at low tide, but at a higher level than *I. lineolatus*.

ISCHNOCHITON CONTRACTUS (Reeve, 1847).

Chiton contractus Reeve, Conch. Icon., IV., 1847, pl. XV., f. 78.
Ischnochiton decussatus Pilsbry, Nautilus VIII., 1895, p. 129.

Loc. 1. 7; on rocks adjacent to Posidonia beds.

ISCHNOCHITON CARIOSUS (Dall, 1878).

Heterozona cariosa Dall, Proc. U.S. Nat. Mus., 1878, p. 331.
Anisoradsia mawlei saundersi Ashby, Tr. R. Soc. S. Aust., XLII., 1918, p. 82.

Loc. 1. 3.

ISCHNOCHITON VIRGATUS (Reeve, 1847).

Chiton virgatus Reeve, Conch. Icon., IV., 1847, pl. XXVIII., f. 192.

Loc. 3; in shallow pools.

Family PLAXIPHORIDAE.

PONEROPLAX COSTATA (Blainville, 1825).

Chiton costatus Bl., Dict. Sci. (Levrault), XXXVI., 1825, p. 548.

Loc. 3; one taken at high tide mark.

Family CHITONIDAE.

ANTHOCHITON EXOPTANDUS (Bednall, 1897).

Chiton exoptandus Bedn., Pr. Mal. Soc., II., 1897, p. 152, text f. and pl. XII., f. 7.

One juvenile attached to *Pinna dolabrata* Lk., dredged in four fathoms off N.W. of Reevesby Island.

Family CRYPTOPLACIDAE.

CRYPTOPLAX STRIATA (Lamarck, 1819).

Chitonellus striatus Lamk., Anim. S. Vert., VI., 1819, p. 317.

Loc. 1; dredged in shallow water.

Class GASTROPODA.

Family HALIOTIDAE.

HALIOTIS (NOTOHALIOTIS) IMPROBULUM Iredale, 1924.

Haliotis naevosum improbulum Iredale. Proc. Linn. Soc. N.S.W. XLIX., pt. 3, p. 222, 1924.

Loc. 1, 2, 4; common.

HALIOTIS (NEOHALIOTIS) EMMAE (Gray, 1846).

Haliotis emmae Gray, Reeve Conch. Icon., III., 1846, pl. 10, f. 29.

Loc. 1, 2. 4.

HALIOTIS (NEOHALIOTIS) SCALARIS (Leach, 1814).

Padollus scalaris Leach, Zool. Miscell., I., 1814, p. 66, pl. 28.

Loc. 1, 2; two specimens. Closely allied to *N. emmae*.

HALIOTIS (EXOHALIOTIS) CYCLOBATES (Peron, 1816).

Haliotis cyclobates Peron, Voy. Terr. Aust., II., 1816, p. 8.

Loc. 1, 2, 3, 4.

Family FISSURELLIDAE.

SCUTUS ANATINUS (Donovan, 1820).

Patella anatinus Don., in Ree's Encyclop. Conch., 1820, pl. XVI.

Loc. 1, 2; large specimens on reefs at extremely low tide.

TUGALI CICATRICOSUS (Adams, 1851).

Tugalia cicatricosa Adams, Thes. Conch., III., 1863, p. 222, pl. 219, f. 14.

Loc. 2; one live specimen.

Family PATELLIDAE.

CELLANA RUBRAURANTIACA (Blainville, 1825).

Patella rubaurantiaca Bl., Dict. Sci. Nat. (Levrault), XXXVIII., 1825, p. 110.

Helcioniscus limbatus Philippi, Abbild. und Besch. Conch., III., p. 71. pl. III., f. 2, 1849.

Loc. 2; on rocks, large, typical.

CELLANA TRAMOSERICA (Sowerby, 1825).

Patella tramoserica Sow., Cat. Shells Tankerville, 1825, p. 30.

Patella variegata Bl., Dict. Sci. Nat. (Levrault), XXXVIII., 1825, p. 101.

Loc. 1, 2; on rocks, common.

Family LOTTIIDAE.

PATELLOIDA ALTICOSTATA (Angas, 1865).

Patella alticostata Angas, P.Z.S., 1865, p. 56, pl. II., f. 11.

Loc. 2; fairly common.

Family TROCHIDAE.

CLANCULUS (ISOCLANCULUS) WEEDINGI sp. nov.

(Pl. vii., fig. 2.)

Depressedly conoid, thick, falsely umbilicate, dark reddish blue, last whorl with four equal granulose lirae on the upper part of the whorl and five on the base; whorls five, first eroded whitish, the last rapidly descending towards the aperture which is somewhat contracted, outer lip denticulate within, a larger denticle above and below, the lower one separated by a notch from the basal tubercle of the columella.

Holotype; height 9 mm., diam. 11.5 mm.; Reevesby Island (Reg. No. D.13304, S.A. Museum).

Well known to South Australian collectors for many years. The Rev. Weeding took good specimens at Port Hughes.

In size, shape and regularity of the sculpture it is quite distinct from its nearest ally *C.* (*I.*) *dunkeri,* and differs from *C.* (*I.*) *yatesi* in the rounded whorls and spaced granulose spiral lirae. At a casual glance this species has a marked resemblance to *Micrastraea rutidoloma* in size, shape, and sculpture, but it is quite distinct in the clanculoid aperture features.

Loc. 1; two specimens in shell sand.

AUSTROCOCHLEA TORRI Cotton and Godfrey, 1934.

Austrocochlea torri C. and G., S. Aust. Nat., Vol. XVI. (1), 1934, pl. 1.

Loc. 1, 2, 3, 4, 5, 6, 7; on rocks.

AUSTROCOCHLEA CONCAMERATA (Wood, 1828).

Trochus concamerata Wood, Index Test., suppl. 1828, pl. 6, f. 35.

Trochus striolatus Quoy and Gaimard, Zool. de L'Astrolabe, III., 1834, p. 253, pl. 63, f. 18, 22.

Loc. 1, 2, 3, 4, 5, 6, 7; on rocks at low time.

Family STOMATELLIDAE.

STOMATELLA IMBRICATA Lamarck, 1816.

Stomatella imbricata Lamk., Encycl. Meth., 1816, p. 10, pl. 450, f. 2.

Loc. 2, 4, 5; on rocks.

HERPETOPOMA ANNECTANS (Tate, 1893).

Euchelus annectans Tate, Tr. R. Soc. S. Aust., XVII., 1893, p. 196.

Loc. 1; in shell sand.

Family TURBINIDAE.

TURBO (SUBNINELLA) UNDULATUS (Martyn, 1784).

Limax undulatus Martyn, Univ. Conch., 1784, f. 29.

Loc. 2; one fragment.

Turbo (Ninella) torquatus (Gmelin, 1784).

Turbo torquatus, Gmel., Syst. Nat. Bed., p. 3597, No. 106.
Limax stamineus Martyn, Univ. Conch., 1784, p. 71.

Loc. 2, 6; broken shells on flat rocks, evidently dropped and broken by the Pacific Gull.

Turbo (Euninella) gruneri Philippi, 1846.

Turbo gruneri Phil., Conch. Cab., 1846, p. 52, pl. 12, f. 7. 8.

Loc. 1; four specimens.

Not previously assigned to a subgenus; the new subgenus *Euninella*, here introduced for *T. gruneri*, differs from other subgenera of *Turbo* as follows. Operculum paucispiral with smooth outer surface, resembling those of *T. (Subninella) undulatus* and *T. (Dinassovica) jourdani*, with curved, ear-like processes like those of *T. (Ninella) torquatus*, but much less valid; shell imperforate like that of *jourdani*, which also has a tendency to spiral ribbing when juvenile. The new subgenus seems to have affinities with the subgenus *Dinassovica*, but is distinguished by the differences noted above.

Turbo (Dinassovica) jourdani Kiener, 1839.

Turbo jourdani Kiener, Rec. Zool. Soc. Cuvier, 1839, p. 324.
Dinassovica verconis Iredale, Pr. Zool. Soc. N.S.W., VIII., pl. 4, 1937, p. 247.

Examination of a series of Western Australian and South Australian specimens convinces me that *verconis* Iredale, is merely a variant of *jourdani*.

Loc. 2; a complete shell 170 mm. high, 150 mm. wide.

Ballastraea squamifera (Koch, 1844).

Turbo squamiferus Koch, Philippi, Abbild., I., 1844, p. 138, pl. 4, f. 9.

Loc. 1, 2; numerous.

Micrastraea gen. nov.

Shell small, depressed, solid, imperforate; whorls five, plicate at the sutures, the folds fainter and usually bifurcating near the periphery; spiral lirae cut the folds into indistinct granules and on the base form coarse granules; aperture small, oblique; columellar callus spread over the umbilical region, and excavate, the outer rim forming a tubercle; operculum spirally ribbed, having a granular surface. Genotype, *Trochus aureus* Jonas, 1844.

The genotype has been recorded from numerous places in the Flindersian Region, and has been located in various genera. Pilsbry places it in *Cyclocantha* Swainson, remarking, "A very attractive little species, quite distinct from its nearest allies." Swainson records it as *Carinidea granulata*, and Tenison-Woods as *Carinidea tasmanica* in 1877 and *Carinidea ornata* in 1876. *Carinidea* does not appear to have any relationship to the present species and Pilsbry has remarked on its distinctions from other species of *Cyclocantha*. The above genus is therefore introduced.

MICRASTRAEA AUREA (Jonas, 1844).

Trochus aureus Jonas, Zeits, Malak., 1844, p. 168.

Loc. 1, 2, 3.

MICRASTRAEA RUTIDOLOMA (Tate, 1893).

Turbo (Astralium) rutidoloma Tate, Tr. R. Soc. S. Aust., 1893, p. 192.

Loc. 1.

Family EUTROPHIDAE.

PHASIANELLA AUSTRALIS (Gmelin, 1788).

Buccinum australe Gmel., Syst. Nat., 1788, p. 3490, No. 173.

Loc. 1; common.

PHASIANELLA, VENTRICOSA Swainson, 1822.

Phasianella ventricosa Swainson, Cat. Coll. Shells Bligh, 1822, P. 15.

Loc. 1; common.

Family NERITIDAE.

NERITA (MELANERITA) MELANOTRAGUS Smith, 1884.

Nerita melanotragus Smith, Zool. Alert., 1884, p. 69.

Loc. 1, 2, 3, 4, 5, 6, 7; common on reefs.

Family LITTORINIDAE.

MELARHAPHE UNIFASCIATA (Gray, 1826).

Littorina unifasciata Gray, King's Survey Aust., Append., II, 1826, p. 483.

Melarhaphe mauritiana Reeve, Conch. Icon., X., 1857, pl. 17, f. 100.

Loc. 3; common on gneissic rocks.

Family HIPPONICIDAE.

SABIA (SABIA) CONICA (Schumacher, 1817).

Amalthea conica Schum., Essai, 1817, p. 81, pl. 21, f. 4.

Loc. 1, 2, 3, 4.

SABIA (ANTISABIA) FOLIACEA (Quoy and Gaimard, 1835).

Hipponix foliacea Q. and G., Zool. de l'Astrolabe, III., 1835, p. 434, pl. 72, f. 41-45.

Loc. 1, 3, 4; in shell sand.

SABIA (ANTISABIA) ERMA sp. nov.

(Pl. vii., fig. 8.)

Shell conical, thick concentrically distantly frilled; frills numbering sixteen, smooth except for microscopic, obsolete, interrupted short radials; protoconch smooth, conical, set in the middle of the first frill pointing laterally and overhanging the base.

Holotype, height 9 mm., width 19 mm.; Reevsby Island (Reg. No. D.13306, S.A. Musuem).

This species has been taken at various places between Yorke Peninsula, S. Aust., and Rottnest, W.A. In South Australia it has been confused with *foliacea* and in Western Australia with *antiquata* Linne, a South American species.

Family CAPULIDAE.

CAPULUS BANKSI sp. nov.

(Pl. vii., fig. 7.)

Shell large, conical, and thin; sculpture of numerous, fine, regular concentrics formed by the edges of very weak concentric frills which are not prominent; the frills are sculptured by microscopic numerous, packed short radials; protoconch spiral, small, overhanging the base of the shell; base regular, ovate; a fine periostracum covers the shell and bristles from it project from the edges of the concentric lamellae.

Holotype, height 11 mm., width 21 mm.; Reevesby Island, shallow water. (Reg. No. D.13307, S.A. Museum.)

One specimen only was taken but there is another in the S. Aust. Museum taken by Dr. Torr at Neptune Island.

Family CERITHIIDAE.

BITTIUM (BATILLARIELLA) ESTUARINUM Tate, 1893.

Bittium estuarinum Tate, Tr. R. Soc. S. Aust., XVII., 1893, p. 190, pl. 1, f. 12.

Loc. 1; dead specimens in sands at 2 feet, but no living examples. The South Australian Museum has numerous specimens from Yalata Station, 30 miles north of Fowlers Bay, taken at 1 foot beneath land surface by Mrs. D. Bates.

BITTIUM (EUBITTIUM) LAWLEYANUM Crosse, 1863.

Bittium lawleyanum Crosse, Journ. de Conch., XI., 1863, p. 87., pl. 1, fig. 4.

Loc. 1; living on weeds in shallow water.

Family SCALIDAE.

Iredale has elevated Boury's subgenera of this family to generic rank and has added a few extra genera; some may prove, on further study, to be synonyms of Boury's earlier subgenera For this reason all are here treated as subgenera.

SCALA (LAEVISCALA) GODFREYI sp. nov.

(Pl. vii., fig. 3.)

Shell elongate, whorls ten, thin, varices thin, well spaced, rolled back, continuous, numbering seven on the body whorl; interstices very finely irregularly, obsoletely spirally striate, and more finely longitudinally striate; mouth oval, lips complete; basal rib narrow.

Holotype, length 23 mm., breadth 8 mm.; Reevesby Island (Reg. No. D.13305, S.A. Museum). This holotype is an average sized specimen.

The species has been misnamed *aculeata* Sowerby, from Hong Kong. The nearest described species is *tacita* Iredale, from Sydney Harbour. The present species differs in having much less regular and less marked interstitial sculpture, resembling rather that of *minora* Iredale.

SCALA (PLASTISCALA) VERCONIS sp. nov.

(Pl. vii., fig. 5.)

Shell small, weakly sculptured, with low fairly sharp longitudinal ribs crossed by concentric lirae; adult whorls seven, protoconch of one and a half, smooth, mamillate whorls; imperforate; aperture subrotund, about twenty-four longitudinal ribs on the body whorl are crossed by numerous spiral lirae, basal cord very indistinct.

Holotype, length 8 mm., breadth 2.3 mm.; Reevesby Island, in shell sand (Reg. No. D.13300, S.A. Museum).

This species is related to the Peronian *morchi* Angas but differs in the greater validity of the sculpture and general appearance. In the Peronian Region we find *morchi* and the deeper water subspecies *bentha* and *profundior*. In the Flindersian Region we have *verconis* and the deeper water *invalida*, but the latter is so distinct in sculpture that it is retained as a full species.

SCALA (POMISCALA) REEVESBYI sp. nov.

(Pl. vii., fig. 1.)

Shell medium size, apical angle wide; imperforate; whorls six, sculptured with longitudinal lamellae continuous from whorl to whorl; interspaces smooth, faint basal cord present; protoconch of one and a half, smooth, depressed whorls; twelve longitudinal lamellae on the last whorl.

Holotype, length 26 mm., breadth 12 mm.; Reevesby Island (Reg. No. D.13299, S.A. Museum).

One specimen only was taken. This species can be distinguished on sight from the Peronian *perplicata* Iredale by the much more slender form and less developed basal rib.

Family CYMATIIDAE.

NEGYRINA SUBDISTORTA (Lamarck 1822).

Triton subdistortum Lamk., Anim. S. Vert., VII., 1822, p. 186.

Loc. 1; one typical, the others are a more slender finer sculptured rounded-whorl form commonly found in South Australia. A series proves that they are variants of one species.

Family CASSIDIDAE.

HYPOCASSIS FIMBRIATA (Quoy and Gaimard, 1833).

Cassis fimbriata Q. and G., Zool de l'Astrolabe II., 1833, p. 569, pl. 43, f. 78.

Loc. 1, 3; one small and two large specimens, the former resembling the subspecies, *decresensis* Hedley.

Family CYPRAEIDAE.

ZOILA THERSITES (Gaskoin, 1848).

Cypraea thersites Gask., P.Z.S., 1848, p. 90.

Loc. 1; six specimens. Common, alive, off west coast of Reevesby Island, at about 2 fathoms.

NOTOCYPRAEA VERCONIS Cotton and Godfrey, 1932.

Notocypraea verconis C. and G., S. Aust. Nat., XIII., 1932, p. 41, pl. 1, f. 8.

Loc. 1, 2, 3, 4.

AUSTROCYPRAEA REEVEI (Sowerby, 1832).

Cypraea reevei Sow., Conch. Illus., 1832, pl. 8, f. 52.

Loc. 1; one specimen.

Family VOLUTIDAE.

AMORENA UNDULATA (Lamarck, 1804).

Voluta undulata Lamk., Ann. Mag. Nat. Hist., V., 1804, p. 157, pl. 12, f. 1.

Loc. 1; numerous.

ERICUSA FULGETRUM (Sowerby, 1825).

Voluta fulgetrum Sow., Tank. Cat., 1825, pls. 4, 5.

Loc. 1, 3, 4; one living specimen approaches the variety *dictua* Verco.

LYRIA MULTICOSTATA (Broderip, 1827).

Voluta multicostata Brod., Zool. Journ., III., 1827, p. 82, pl. 3. f. 2.

Loc. 1; numerous.

Family CONIDAE.

FLORACONUS ANEMONE (Lamarck, 1810).

Conus anemone Lamk., Ann. du Mus., XV., 1810, p. 272.

Loc. 1, 2, 3, 4; common, varying from medium to long spires.

PARVICONUS RUTILUS (Menke, 1843).

Conus rutilus Menke, Moll. Nov. Holl., 1843, p. 27.

Loc. 1; three specimens.

Family BUCCINIDAE.

COMINELLA LINEOLATA (Lamarck, 1822).

Buccinum lineolatum Lamk., Anim. S. Vert., VII., 1822, p. 267.

Loc. 1, 2, 3, 4, 5; numerous.

Family NASSARIIDAE.

RETICUNASSA PAUPERA (Gould, 1850).

Nassa paupera Gould, Pr. Boston Nat. Hist. Soc., III., 1850, p. 155

Loc. 2; in shell sand; very variable.

NIOTHA PYRRHUS (Menke, 1843).

Buccinum pyrrhum Menke, Moll, Nov. Holl., 1843, p. 21.
Alectrion victorianus Ird., Tr. N.Z. Inst., 1915, p. 467.

Loc. 2; numerous on tidal sand flats.

PARCANASSA PAUPERATA (Lamarch, 1822).

Buccinum pauperatum Lamk., Anim. S. Vert., VII., 1822, p. 278.

Loc. 2; numerous on tidal sand flats.

NASSARIUS PARTICEPS (Hedley, 1915).

Arcularia particeps Hedley. Pr. Linn. Soc. N.S.W., XXXIX., 1915, p. 738.

Loc. 1; two shells.

Family PYRENIDAE.

ZEMITRELLA NUX (Reeve, 1859).

Columbella nux Reeve, Conch. Icon., XI., pl. XXXV., f. 227, 1859.

Loc. 1; two specimens.

The specimens have been allotted to Reeve's species *nux*, type locality Port Adelaide, in prefence to Gaskoin's species *pulla*, described without type locality but allowed by previous authors in the South Australian list. The two specimens agree fairly well with Reeve's figure.

Zemitrella acuminata (Menke, 1843).

Buccinum acuminatum Menke, Moll. Nov. Holl., 1843, p. 20.

Loc. 1; numerous.

Zemitrella purpureocincta (Verco, 1910).

Pyrene menkeana purpureocincta Verco, Tr. R. Soc. S. Aust., XXXIV., 1910, p. 347.

Loc. 1; one specimen.

Family MURICIDAE.

Pteronotus triformis (Reeve, 1845).

Murex triformis Reeve, Conch. Icon., III., 1845, pl. 13, f. 53.

Loc. 1, 2, 3.

Family THAIDIDAE.

Neothais textiliosa (Lamarck, 1822).

Purpura textiliosa Lamk., Anim. S. Vert., VII., 1822, p. 77.

Loc. 2, 3; six specimens; one large shell contained a hermit crab, *Paguristes frontalis* Milne Edwards.

Family LAOMIDAE.

Paralaoma stabilis (Iredale, 1937).

Helix arenicola Tate, Pr. Linn. Soc. N.S.W., II., 1878, p. 291.

Paralaoma stabilis Ird., S. Aust. Nat., XVIII., 2, 1937, p. 20.

Reevesby Island; numerous examples taken by J. Clark and the author.

Miselaoma reevesbyi sp. nov.

(Pl. vii., fig. 4.)

Shell small, fragile, horn coloured, sinistral, very narrowly umbilicated, spire elevated, protoconch depressed; whorls including protoconch four and a half, flatly rounded; subangulate, sutures impressed; sculpture of axial fine striae on the adult whorls; protoconch microscopically interruptedly spirally lirate.

Holotype, height 1.4 mm., breadth 1.5 mm.; Reevesby Island (Reg. No. D.13296, S.A. Museum).

Three specimens in all have been picked out from the numerous small shells taken on the Island. At first this species was thought to be the immature tip of *Omegapilla australis*. The subangulate whorls, large size and different shape, distinguish this species from the Victorian *Laoma sinistra* Gabriel.

Family SUCCINEIDAE.

Succinea (Austrosuccinea) australis (Ferussac, 1821).

Helix australis Ferussac, Tabl. Syst. Limacons, pt. 2, 1821, p. 31, pl. XI., fig. 11.

Reevesby Island; numerous.

SUCCINEA (ARBORCINEA) ARBOREA Angas, 1864.

Succinea arborea Angas, P.Z.S., 1864, p. 523.

Reevesby Island; under bark of *Myoporum insularae.*

Family VERTIGINIDAE.

THEMAPUPA ADELAIDAE (Angas, 1864).

Buliminus (Chondrula) adelaidae Angas, P.Z.S., 1863, p. 522.

Reevesby Island; three specimens.

OMEGAPILLA AUSTRALIS (Angas, 1864).

Vertigo australis Angas, P.Z.S., 1863, p. 522.

Reevesby Island; numerous.

AUSTRALBINULA MARGARETAE (Cox, 1868).

Pupa margaretae Cox, Mon. Aust. Land Shells, 1868, p. 80, pl. XIV., f. 20*a*.

Reevesby Island; numerous.

Family CHAROPIDAE.

DISCOCHAROPA INSULARIS sp. nov.

(Pl. vii., fig. 6.)

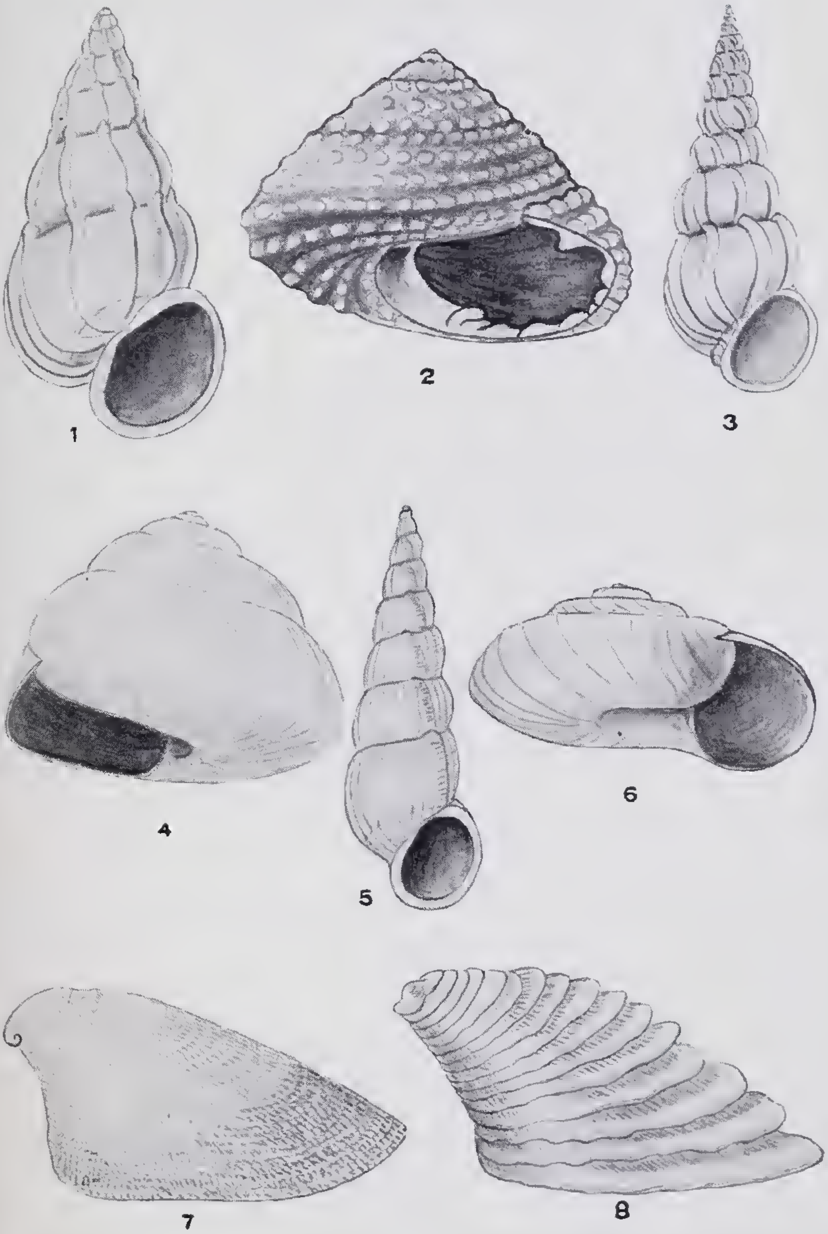
Shell small, thin, flattened, horn coloured; whorls three, sculptured with distant, radial ribs, the interstices filled with much finer accremental striae; protoconch large, smooth, of one and a half whorls; umbilicus wide, mouth simple.

Holotype, height 1 mm., breadth 2 mm.; Reevesby Island (Reg. No. D.13297, S.A. Museum).

Reevesby Island; four specimens. Readily separable from the Central Australian *planorbulina* Tate.

Explanation of Plate.

1. Scala (Pomiscala) reevesbyi sp. nov. × 2.
2. Clanculus (Isoclanculus) weedingi sp. nov. × 4
3. Scala (Laeviscala) godfreyi sp. nov. × 2.
4. Miselaoma reevesbyi sp. nov. × 28.
5. Scala (Plastiscala) verconis sp. nov. × 3. 6.
6. Discocharopa insularis sp. nov. × 22.
7. Capulus banksi sp. nov. × 2.4.
8. Sabia (Antisabia) erma sp. nov. × 3.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5. *Pisces.*

By J. S. GUEST and D. B. ROBERTSON.

Methods adopted for procuring specimens were:—

(*a*) Rock pools were poisoned with chloride of lime or hand nets used.

(*b*) A 75 fathom seine net was used extensively at Home Bay, the only situation suitable for netting on Reevesby Island.

(*c*) Hand lines were used, mainly in water up to 6 fathoms.

(*d*) Dredging was carried out mainly off the west and south coasts of Reevesby Island.

Although the most detailed study was made at Reevesby Island and most of the species were obtained at or near that island, a less detailed survey of the rest of the group indicated that most of the Reevesby fish were common throughout.

As well as fish of economic importance such as Whiting (*Sillaginodes punctatus*), Sweep (*Scorpis georgianus*) and Schnapper (*Pagrosomus auratus*) which were extensively caught by local fishermen, many other excellent edible fish were obtained, such as Trevally (*Caranx georgianus*), Garfish (*Hyporhamphus intermedius*), and Flathead (*Platycephalus bassensis*). Poorer types of fish such as Australian Salmon, Parrot Fish, and Leather Jackets were present in enormous numbers, while the commonest inhabitants of rock pools were the Jumping Blenny and Zebra Fishes.

The nomenclature adopted in this report (except in the case of *Spheroides pleurogramma*) is that used by Waite in the Catalogue of the Fishes of South Australia (Rec. S.A. Mus., ii., 1921-24, pp. 1-208) and in "The Fishes of South Australia" (Brit. Sci. Guild Handbook, Adelaide, 1923). Only the most significant references to synonymy are given.

Sub-class ELASMOBRANCHII.

Order SELACHII.

Family HETERODONTIDAE.

HETERODONTUS PHILIPPI (Bloch and Schneider, 1801). (Port Jackson Shark.)

Squalus philippi Bl. and Schn., Syst. Ichth., 1801, p. 134.

Heterodontus philippi (Bl. and Schn.). Blainville, Bull. Soc. Phil., 1816, p. 121.

Several egg cases of this species were found on the beaches of Reevesby Island.

Order BATOIDEI.

Family RHINOBATIDAE.

TRIGONORRHINA FASCIATA (Müller and Henle, 1837). (Fiddler).

Trigonorrhina fasciata Müller and Henle, Mag. Nat. Hist., (2), ii., 1837, p. 90. and Plagiost, 1838, p. 124, pl. xlii.

Family MYLIOBATIDAE.

MYLIOBATIS TENUICAUDATUS (Hector, 1877). (Eagle Ray.)

Myliobatis tenuicaudatus Hector, T.N.Z. Inst., ix., 1877, p. 468.

Very commonly seen in shallow water.

Sub-class TELEOSTOMI.

Order ISOSPONDYLI.

Family CLUPEIDAE.

STOLEPHORUS ROBUSTUS (Ogilby, 1898). (Blue Sprat.)

Spratelloides robustus Ogilby, P.L.S. N.S.W., xxii., 1898, p. 64.

Stolephorus robustus (Ogilby), Waite, Mem. N.S.W. Nat. Club, ii., 1904, p. 12.

Family GONORHYNCHIDAE.

GONORHYNCHUS GREYI (Richardson, 1845). (Sand Fish.)

Rhynchana greyi Rich., Zool. Erebus and Terror, 1845, p. 44, pl. xxix., figs. i-vi and text fig.

Gonorhynchus greyi (Rich.), Gunther, Cat. Fish. Brit. Mus., vii., 1868, p. 373.

One specimen, 33 cm. in length, was taken.

Order NEMATOGNATHI.

Family PLOTOSIDAE.

CNIDOGLANIS MEGASTOMA (Richardson, 1845). (Estuary Catfish.)

Plotosus megastomus Rich., *loc. cit.*, 1845, p. 31, pl. xxi., figs. i-iii.

Cnidoglanis megastoma (Rich.), Gunther, Cat. Fish. Brit. Mus., v., 1864, p. 27.

Order SYMBRANCHII.

Family SYMBRANCHIDAE.

CHEILOBRANCHUS RUFUS (Macleay, 1881). (Shore Eel.)

Cheilobranchus rufus Macleay, P.L.S., N.S.W., vi., 1881, p. 266.

Found in numbers in almost every rock pool examined throughout the group.

Order SOLENICHTHYES.

Family SYNGNATHIDAE.

LISSOCAMPUS CAUDALIS (Waite and Hale, 1921). (Smooth Pipefish.)

Lissocampus caudalis Waite and Hale, Rec. S.A. Mus., i., 1921, p. 306, fig. xlvi.

Order SYNENTOGNATHI.

Family HEMIRHAMPHIDAE.

HYPORHAMPHUS INTERMEDIUS (Cantor, 1842). (Garfish.)

Hemirhamphus intermedius Cantor, A.M.N.H., ix., 1842, p. 485.
Hyporhamphus intermedius (Cant.), Waite, Rec. S.A. Mus., ii., 1921, p. 65, fig. 98.

Commonly netted in Home Bay.

Order PERCOMORPHI.

Sub-order PERCESOCES.

Family ATHERINIDAE.

ATHERINA MICROSTOMA (Gunther, 1861). (Large-scaled Atherine.)

Atherina microstoma Gunth., Cat. Fish. Brit. Mus., iii., 1861, p. 401.

Family MUGILIDAE.

AGONOSTOMUS FORSTERI (Bloch and Schneider, 1801). (Freshwater Mullet, Conmuri.)

Albula forsteri Bl. and Schn., *loc. cit.*, 1801, pp. xxxii and 120.
Agonostoma forsteri (Bl. and Schn.), Gunther, *loc. cit.*, 1861, p. 465.

Only juvenile specimens taken.

Family SPHYRAENIDAE.

SPHYRAENA NOVAE-HOLLANDIAE (Gunther, 1860). (Snook, Short-finned Pike.)

Sphyraena novae-hollandiae Gunth., Cat. Fish. Brit. Mus., ii., 1860, p. 335.

Netted at Home Bay.

Sub-order PERCOIDEA.

Division PERCIFORMES.

Family SILLAGINIDAE.

SILLAGINODES PUNCTATUS (Cuvier and Valenciennes, 1829). (Spotted Whiting.)

Sillago punctata Cuv. and Val., Hist. Nat. Poiss., iii., 1829A, p. 413.
Sillaginodes punctatus (Cuv. and Val.), Gill, Proc. Acad. Nat. Sci. Phil., 1861, p. 505.

Commonly caught on handlines in 3-4 fathoms.

Family CARANGIDAE.

CARANX GEORGIANUS (Cuvier and Valenciennes, 1833). (Trevally.)

Caranx georgianus Cuv. and Val., Hist. Nat. Poiss., ix., 1833, p. 85.

Caught in large numbers at Reevesby and Little English Islands.

SERIOLA GRANDIS (Castelnau, 1872). (Yellowtail.)

Seriola grandis Castelnau, P.Z.S. Vic., i., 1872, p. 115.

Family ARRIPIDIDAE.

ARRIPIS TRUTTA (Forster, 1801). (Australian Salmon.)

Sciaena trutta Forster, in Bloch and Schneider, *loc. cit.*, 1801, p. 542.

Arripis trutta (Forster), Gill, Mem. Nat. Acad. Sci., vi., 1893, p. 116.

Enormous shoals seen in shallow water throughout the group.

ARRIPIS GEORGIANUS (Cuvier and Valenciennes, 1831). (Tommy Rough, Wankaldi.)

Centropristes georgianus Cuv. and Val., Hist. Nat. Poiss., vii., 1831, p. 451.

Arripis georgianus (Cuv. and Val.), Jenyns, Voy. Beagle, 1842, p. 14.

Very common.

Family SCIAENIDAE.

SCIAENA ANTARCTICA (Castelnau, 1872). (Butterfish, Mulloway.)

Sciaena antarctica Castelnau, *loc. cit.*, 1872, p. 100.

Noted in clear water off Roxby Island.

Family MULLIDAE.

UPENEUS POROSUS (Cuvier and Valenciennes, 1829). (Red Mullet.)

Upeneus porosus Cuv. and Val., *loc. cit.*, 1829A, p. 455.

One specimen taken.

Family SPARIDAE.

PAGROSOMUS AURATUS (Forster, 1801). (Schnapper.)

Sciaena aurata Forster, in Bloch and Schneider, *loc. cit.*, 1801, p. 266.

Pagrosomus auratus (Forster), Gill, *loc. cit.*, 1893, pp. 97, 116, 123.

Common: schnapper grounds west of Roxby used by fishermen.

Family SCORPIDIDAE.

SCORPIS GEORGIANUS (Cuvier and Valenciennes, 1831). (Banded Sweep.)

Scorpis georgianus Cuv. and Val., Hist. Nat. Poiss, viii., 1831, p. 503, pl. ccxlv.

Caught in large numbers on hand lines.

Family GIRELLIDAE.

MELAMBAPHES ZEBRA (Richardson, 1846). (Zebra Fish.)

Crenidens zebra Rich., Zool. Ereb. Terr., 1846, p. 70.
Tephraeops zebra (Rich.), Gunther, Cat. Fish. Brit. Mus., i., 1859, p. 432.
Melambaphes zebra (Rich.), Waite, Fishes S. Aust., 1923, p. 137.

Very common in all rock pools examined.

Family ENOPLOSIDAE.

ENOPLOSUS ARMATUS (Shaw, 1790). (Old Wife.)

Chaetodon armatus Shaw, in White's Voy. N.S.W., 1790, p. 254. pl. xxxix., fig. i.
Enoplosus armatus (Shaw), Cuv. and Val., Hist. Nat. Poiss., ii., 1828, p. 133, pl. xx.

Division CIRRHITIFORMES.
Family CHEILODACTYLIDAE.

GONIISTIUS VIZONARIUS (Kent, 1887). (Magpie Perch.)

Cheilodactylus gibbosus Castelnau, *loc. cit.*, 1872, p. 75 (not Rich.).
Chilodactylus vizonarius Kent, P.R.S. Tas., 1887, p. xxx, 48.
Goniistius vizonarius (Kent), McCulloch, Endeavor Res., i., 1911, p. 64, pl. xi.

Division LABRIFORMES.
Family LABRIDAE.

Members of this family (Parrot Fishes) were extremely common on weedy and rocky bottoms.

PSEUDOLABRUS PSITTACULUS (Richardson, 1840). (Rosy Parrot Fish.)

Labrus psittaculus Rich., P.Z.S., 1840, p. 26 and Zool. Ereb. Terr., 1848, p. 129, pl. lvi., figs. vii-x.
Pseudolabrus psittaculus (Rich.), McCulloch, *loc. cit.*, 1911, p. 77, fig. xix.

PSEUDOLABRUS FUCICOLA (Richardson, 1840). (Purple Parrot Fish.)

Labrus fucicola Rich., *loc. cit.*, 1840, p. 26 and *loc. cit.*, 1848, p. 127, pl. liv., figs. i., ii.
Pseudolabrus fucicola (Rich.), Gill, *loc. cit.*, 1893, p. 116.

PSEUDOLABRUS CELIDOTUS (Forster, 1801). (Spotty.)

Labrus celidotus Forster, in Bloch and Schneider, *loc. cit.*, 1801, p. 265.
Pseudolabrus celidotus (Forster), Gill, *loc. cit.*, 1893, pp. 98, 117.

PSEUDOLABRUS TETRICUS (Richardson, 1840). (Blue-throated Parrot Fish.)

Labrus tetricus Rich., *loc. cit.*, 1840, p. 25 and *loc. cit.*, 1848, p. 126, pl. lv., figs. i.-iv.
Pseudolabrus tetricus (Rich), Waite, *loc. cit.*, 1921, p. 130

PSEUDOLABRUS PUNCTULATUS (Gunther, 1862). (Blue-spotted Parrot Fish.)

Labrichthys punctulata Gunther, Cat. Fish. Brit. Mus., iv., 1862, p. 118.
Pseudolabrus punctulatus (Gunth.), Gill, P.U.S. Nat. Mus., xiv., 1892, p. 401.

PICTILABRUS LATICLAVIUS (Richardson, 1839). (Senator Fish.)

Labrus laticlavius Rich., P.Z.S., 1839, p. 99 and *loc. cit.*, 1848, p. 128, pl. lvi., figs. iii.-vi.
Pictilabrus laticlavius (Rich.), Gill, *loc. cit.*, 1892, p. 403.

Family ODACIDAE.

ODAX sp.

Sub-order GOBIOIDEA.

Family GOBIIDAE.

GOBIUS HINSBYI (McCulloch and Ogilby, 1919). (Girded Goby.)

Gobius pictus Castelnau, *loc. cit.*, 1872, p. 124 (not Malm.).
Gobius hinsbyi Johnston, P.R.S. Tas., 1903, p. x. (name only); *idem*, McCulloch and Ogilby, Rec. Aust. Mus., xii., 1919, p. 215, pl. xxxiii., fig. i

Dredged between Reevesby and Partney Islands.

GOBIUS LATERALIS (Macleay, 1881). (Spotted Goby.)

Gobius lateralis Macleay, P.L.S. N.S.W., v, 1881, p. 602.

Sub-order BLENNIOIDEA.

Family BLENNIIDAE.

BLENNIUS TASMANIANUS (Richardson, 1839). (Blenny.)

Blennius tasmanianus Rich., *loc. cit.*, 1839, p. 99; *idem*, T.Z.S., iii., 1849, p. 129.

Frequently found in rock pools.

OPHICLINUS GRACILIS (Waite, 1906). (Black-backed Snake Blenny.)

Ophiclinus gracilis Waite, Rec. Aust. Mus., vi., 1906, p. 207, pl. xxxvi., fig. vi.

One specimen from Kirkby Island.

CRISTICEPS AUSTRALIS (Cuvier and Valenciennes, 1836). (Weed Fish.)

Cristiceps australis Cuv. and Val., Hist. Nat. Poiss., xi., 1836, p. 402, pl. cccxxxvi.

CLINUS PERSPICILLATUS (Cuvier and Valenciennes, 1836). (Eyed Blenny.)

Clinus perspicillatus Cuv. and Val., *loc. cit.*, 1836, p. 372.

LEPIDOBLENNIUS MARMORATUS (Macleay, 1878). (Jumping Blenny.)

Tripterygium marmoratum Macleay, P.L.S. N.S.W., iii., 1878, p. 34, pl. iii., fig. ii.

Lepidoblennius marmoratus (Macleay), McCulloch and McNeill, Rec. Aust. Mus., xii., 1918, p. 24.

One of the most common species occurring in rock pools.

Order HETEROSOMATA.

Family PLEURONECTIDAE.

AMMOTRETIS TUDORI (McCulloch, 1914). (Bass Flounder.)

Ammotretis tudori McCulloch, Endeavor Res., ii., 1914, p. 124, pl. xxvi.

Order SCLEROPAREI.

Family SCORPAENIDAE.

NEOSEBASTES PANDUS (Richardson, 1842). (Gurnard Perch.)

Scorpaena panda Rich., A.M.N.H., ix., 1842, p. 216.

Neosebastes panda (Rich.), Guichenot, Mem. Soc. Sci. Cherbourg, xiii., 1867, p. (86?).

GYMNAPISTES MARMORATUS (Cuvier and Valenciennes, 1829). (Cobbler.)

Apistus marmoratus Cuv. and Val., Hist. Nat. Poiss., iv., 1829, *b*, p. 416.

Gymnapistes marmoratus (Cuv. and Val.), Swainson, Nat. Hist. Fish., ii., 1839, p. 266.

Family PLATYCEPHALIDAE.

PLATYCEPHALUS BASSENSIS (Cuvier and Valenciennes, 1829). (Sand Flathead.)

Platycephalus bassensis (Cuv. and Val., *loc. cit.*, 1829, *b*, p. 247.

Order PLECTOGNATHI.

Division SCLERODERMI.

Family MONACANTHIDAE.

The following members of this family were very common:—

CANTHERINES AYRAUDI (Quoy and Gaimard, 1824). (Yellow Leather Jacket.)

Balistes ayraud Q. and G., Voy, Uran. et Physic., 1824, p. 216, pl. xlvii., fig. ii.

Cantherines ayraudi (Q. and G.). Waite, *loc. cit.*, 1921, p. 186.

CANTHERINES SETOSUS (Waite, 1899). (Velvet Leather Jacket.)

Monacanthus setosus Waite, Mem. Aust. Mus., iv., 1899, p. 91, pl. xvi.

Cantherines setosus (Waite), Waite and McCulloch, T.R.S.S. Aust., xxxix., 1915, p. 472, pl. xiv.

CANTHERINES MOSAICUS (Ramsay and Ogilby, 1886). (Mosaic Leather Jacket.)

Monacanthus mosaicus Rams. and Ogil., P.L.S. N.S.W. (2), i., 1886, p. 5.

Cantherines mosaicus (Rams. and Ogil.), McCulloch, Endeavor Res., iii., 1915, p. 170, pl. xxxvii., figs. i., ii.

Family OSTRACIONTIDAE.

ARACANA ORNATA (Gray, 1838). (Common Cowfish.)

Aracana ornata Gray, A.M.N.H., i., 1838, p. 110

ARACANA FLAVIGASTRA (Gray, 1838). (Yellow-bellied Cowfish.)

Aracana flavigastra Gray, *loc. cit.*, 1838, p. 110.

Division GYMNODONTES.

Family TETRADONTIDAE.

SPHEROIDES PLEUOGRAMMA (Regan, 1902). (Common Toado.)

Tetrodon pleurogramma Regan, P.Z.S., 1902, p. 300, pl. xxiv., fig. ii.

Spheroides pleurogramma (Regan), McCulloch, Rec. W.A. Mus., i., 1914, p. 227; *idem*, Waite, Rec. S.A. Mus., ii., 1924, p. 486, pl. xxx., fig. ii.

Spheroides lacrimosus Waite, *loc. cit.*, 1923, p. 226.

TETRAODON ARMILLA (Waite and McCulloch, 1915). (Ringed Toado.)

Tetraodon armilla Waite and McCulloch, *loc. cit.*, 1915, p. 475, pl. xv.

H. J. GREEN, Government Printer, Melbourne.

[PROC. ROY. SOC. VICTORIA, 51 (N.S.), PT. II., 1939.]

ART. IX.—*The Problem of Hard Seeds in Subterranean Clover.*

By YVONNE AITKEN, M.Agr.Sc.

[Read 13th October, 1938; issued separately, 24th July, 1939.]

I. INTRODUCTION.
II. THE FORMATION OF HARD SEEDS—
1. Relation of Hardness to Seed Development.
2. Occurrence of Hardness in the Individual Plant.
3. Factors Influencing Formation of Hard and Soft Seeds.
4. Comparison of Hard and Soft Seeds.
III. THE SOFTENING OF HARD SEEDS UNDER NATURAL AND COMMERCIAL CONDITIONS.
IV. THE RELATION OF SEED STRUCTURE TO HARDNESS.
V. DISCUSSION.
VI. SUMMARY.

Introduction.

It has long been known that a seed, though viable, may be unable to germinate under favourable conditions, through either dormancy of the embryo, or an impermeable seedcoat. A seed in which impermeability of the seedcoat prevents water absorption, is termed "hard", whereas a permeable seed is "soft". "Hardseededness" occurs characteristically in the Family Leguminosae and the hard seeds are capable of germination after any treatment which makes the testa pervious, such as cutting by contact with the rough sides of a threshing drum, scratching with sandpaper, slight charring with concentrated sulphuric acid or hot ashes, contact with boiling water. Softening by means of mechanical treatment is important in the commercial harvesting of leguminous crops such as clovers and lucerne. Natural softening in field and store is of significance in the practical value of the species concerned.

The literature on hardseededness has been reviewed by Witte (10). Since 1932, Helgeson (6), Hamly (4), Stevenson (9), and Dutt (3) have contributed valuable information. However, a thorough investigation is still needed over the whole problem of hard seeds in Legumes, in order to understand the sequence of events from the production of a hard seed to its ultimate softening.

Subterranean clover was selected for study on this plan, as a contribution towards such a survey; not only was its formation of hard seeds of economic significance, in its position of the most important annual legume in Australia, but it had the unique characteristic among clovers of burying its seed, and the relation of seed-burial to hardseededness was not known.

The habit of the Subterranean clover plant, its type of flowering, the tendency to bury the flower cluster after fertilization, and the formation of a burr round each group of three or four seeds, are shown in plate XI.

Observations and experiments were made on all available material, including burr of Mt. Barker variety from a commercial grower, commercial samples of seed, and hand-cleaned seed from the strains grown at Burnley Gardens. These were grouped as Early maturing—Dwalganup, Mulwala, Dalliak, Springhurst, and Bacchus Marsh; Midseason—Mt. Barker, White Seed, Mansfield, Nangeela, and Burnerang; and Late maturing—Berlin, Merino, Macarthur, Tallarook, Wenigup, and Bass.

The extent of hardseededness in this clover is indicated by two facts, (1) that each burr usually contains both soft and hard seeds; (2) that in 1937, the percentage of hard seeds varied from 50 per cent. to 95 per cent. in the numerous samples examined less than a month after the burrs of the latest strains had dried—results similar to those of Meadley (7), in the district of Boyup, Western Australia.

Formation of Hard Seeds.

(1) *Relation of Hardness to Seed Development.*

In a normal spring, about one month elapses between fertilization and the growth of the young seed to its maximum size. The seed then dries, and becomes mature.

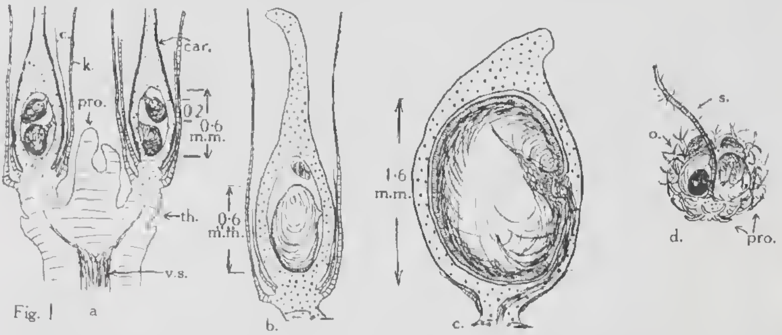


Fig. 1.—Longitudinal sections of the developing ovule of *Trifolium subterraneum*; (*a*) through the florets in a panicle at fertilization, showing two ovules in each ovary; (*b*) through an ovary some days after, showing growth of one ovule only; (*c*) a seed several weeks old, half grown; (*d*) diagram of a mature burr, showing the rosette of infertile calyces round the pods, and a pod opened to show the dried seed within. (v.s. = vascular strand, th. = thalamus, k. = calyx, pro. = primary infertile flowers, c. = petals, car. = carpel, o. = pod, with dried seed exposed, s. = stalk of burr.)

The ovary at fertilization is about 1 mm. long and usually encloses two ovules each about 0.2 mm. long and 0.15 mm. wide (fig. 1*a*). As a rule only one of these ovules develops in each ovary (figs. 1*b-d*). When the seed is about 2 mm. long, it is tightly enclosed by the greenish white membraneous ovary wall.

At this stage the testa is colourless. A faint pink soon appears round the hilum and spreads over the seed. The full-sized seed is dark crimson except at the strophiolar and micropylar regions which are paler, and at the hilum which is white owing to the disc of loose cells connecting it to the vascular strand of the ovary. The normal process of drying results in a reduction in the diameter of the seed from about 4 mm. to about 2 mm. and a change in its colour from crimson to purple-black except round the hilum which remains somewhat lighter.

Changes in the permeability of the developing seed were tested by using 1 per cent. osmic acid. The testas of young seeds were rapidly permeated by the acid over most of their surfaces. As development proceeded, the permeable areas diminished in extent. In seeds at their maximum size, the staining occurred as patches scattered over the surface (fig. 8*a*). From this it may be assumed that entry of water is possible over most of the testa before the seed dries. If staining occurs at the strophiole, it is a thin line across the centre. After the drying, the matured seed remains permeable, forming an "original" soft seed, or becomes hard, and this hardness is of variable duration. The seeds that soften, gradually raise the total soft seed percentage in the burrs despite the later hardening of some of the original soft seed. Osmic acid stains the soft seeds derived from hard, with a black spot at the end of the seed nearer the hilum (fig. 8*c*), while the original soft seeds are stained at the radicle tip, or in nearby patches (fig. 8*b*).

(2) *Occurrence of Hardness in the Individual Plant.*

It was noticed that, in many panicles, all the florets did not open at the same time, and this was followed by uneven development of the seeds, as evidenced by differing sizes, and by the variation in the time at which they began to colour pink. It was probable that this unevenness was connected with nutritional retardation in the less advanced seeds, and that these seeds would tend to remain soft, or develop a hardness of short duration. To test the idea, cotton was tied round the base of retarded florets, and the seed of each was separated from the rest in the burr, after ripening and drying out. There was an indication that least advanced florets in the panicle gave rise to some of the seed that softened first.

The position of the burr above or below the soil surface affects the size and time of drying of the seeds. Among burrs of the same age, those developed above ground are green and half the size of the buried burrs which are white. They dry out much later than those on the surface, because of the lowered maximum temperatures (Table 1) and more moist conditions. The seeds in the buried burrs are slightly larger, and the number of seeds matured per burr more than in the surface burrs; the increase seems due to the longer time for development before

TABLE 1.

Daily maximum and minimum temperatures in degrees Fahrenheit for air, soil surface, and just below surface, November and December, 1938.

Date.	Air.	Soil Surface.	Date.	½-in. below Surface.	Soil Surface.
Nov. 25 ..	52–74	50–103	Dec. 3 ..	50–116	47–125
„ 26 ..	48–82	46–106	„ 7 ..	56–94	52–100
„ 28 ..	60–94	56–108	„ 19 ..	48–112	46–123
„ 29 ..	52–82	46–108	„ 22 ..	40–110	46–122
			„ 28 ..	–112	–131
Average ..	53–83	49–106			
Variation in Max. Temp., 20° F.			Variation in Max. Temp. 10–20° F.		

drying. That length of development is linked with hardseededness was shown in an experiment with a row of plants of Bacchus Marsh strain. Burrs on one side of the row were encouraged to develop below the soil surface, which was kept moist till about a month after the drying of the burrs on the other side, where they had been prevented from burying. Seeds from the buried burrs, after drying on the plants, proved to be slightly more hardseeded than the surface seeds. Further drying of both types under a very low saturation deficit, caused an increased percentage of hard seeds in the buried burrs, which were evidently of higher potential hardseededness than those formed above ground.

The evidence that the stage of development of the seed at drying was important in determining its subsequent hardness, is supported by the distribution of hard and soft seeds according to the position of burrs along a runner. In plants or burrs collected while green, and allowed to dry, seeds from the younger burrs contained a higher percentage of soft seed than from the older—as shown in Table 2. Burrs from a plant of Dalliak strain were among those analysed in greater detail, and shows the same trend in Table 3.

TABLE 2.

Variation in yield of soft seeds along the runner. Burrs from 1937 harvest, Burnley, tested 10th January, 1938; plants cut in November while green. (Approx. 200 seeds per strain.)

Strain.	Percentage of Soft Seeds in Burrs.	
	Basal (First to Third Burrs).	Upper (Sixth Burr and Higher).
Berlin	14	52
Tallarook	1	15
Madrid	16, 25	42, 40
Dalliak	1	14

TABLE 3.

Typical analysis of a plant harvested green. The occurrence of softness according to burr position is stated.

Position of Burr along Runner.	Soft Seeds.	Total Seeds.	Percentage of Soft Seeds
			%
Basal 1	18	76	28
2	19	56	
3	17	47	
Mid 4	19	68	
5	9	31	33
6	21	58	
Upper 7	10	40	
8	14	27	40
9	5	22	
10	5	18	
11	7	12	70
12	7	9	

It would be expected from this, that in a range of strains grown together, the advent of hot, dry weather towards the end of the growing season would tend to dry off the youngest seeds of the later stains before they were fully developed. This would cause a characteristically higher percentage of soft seeds than would occur in earlier strains in which the seed had longer time to

TABLE 4.

Variation in soft seed yield a/c strain and position of flower along runner. (Seeds collected from Burnley plots in mid-November and tested at end of month.)

Strain Maturity.	Name.	Soft Seeds.	Total Seeds.	Percentage Soft a/c Position.
				%
Earliest ..	Dwalganup ..	3	51	Basal .. 0
				Mid .. 6
				Upper .. 20
Early	Mulwala ..	15	43	B. .. 16
				M. .. 65
				U. .. 60
Early-mid ..	Springhurst ..	17	83	B. .. 7
				M. .. 25
				U. .. 41
,, ..	Bacchus Marsh	32	117	B. .. 11
				U. .. 42
Mid-season ..	Mt. Barker ..	6	26	B. .. 22
,, ..	White Seed ..	10	41	B. .. 18
				U. .. 57
,, ..	Mansfield ..	35	64	B. .. 55
,, ..	Nangeela ..	22	56	B. .. 40
,, ..	Burnerang ..	46	48	B. .. 96
Late	Merino ..	31	37	B. .. 84
,, ...	Macarthur ..	36	39	B. .. 93
,, ...	Tallarook ..	16	16	B. .. 100

develop. This seems to be borne out by field observations up to date. A late strain (Tallarook), had a relatively high percentage of soft seed, in December 1937, and a heavy germination in the ground after the rains in January 1938. The early strains (Dwalganup, Dalliak, and Mulwala) had few soft seeds, and a very low germination in the plots. The general correlation of softness with lateness of maturity is seen in Table 4, but the variation in results indicates the necessity for further data on the effect of variety on hardseededness, as distinct from its effect on the time of seed development.

The degree of drying of the seed was found to be important in hard seed formation, when burr from the same varieties was gathered at intervals from October to December 1938. Each set was further dried under standard conditions, and then tested. The longer the seeds were allowed to dry out on the plant, the higher the percentage of hard seed (Table 5).

TABLE 5.

Variation in soft seed yield a/c strain and time of harvesting.

Strain.	Percentage Soft Seeds.—Time of Harvesting, Nov.–Dec., 1938.		
	15/11.	23/11.	14/12.
	%	%	%
Bacchus Marsh	40	..	30
Mt. Barker	72	40	..
White Seed	80	..	23
Macarthur	100	53	..
Tallarook	100	51	18

Observations were made on the variation in hardseededness in the plants of a strain row. In each of several strains, twelve individuals were selected out of about 90, and the burrs dried further under standard conditions before testing in December. There was a wide range, due to a few plants having soft seed percentages well away from the mean.

Strains are chiefly distinguished by their differential response to environmental conditions, particularly as to time of flowering. A previous paragraph has indicated the correlation of late strains with less hardseededness, because of the less development of seeds before drying. A further confirmation of the importance of seed development was obtained by causing a number of strains to begin flowering several weeks earlier than usual for the Melbourne district. Earlier flowering resulted from growing the strains at Swan Hill, Cohuna, and Rutherglen. Sufficient watering enabled the flowering plants in the northern districts

to grow until December, and so lengthened the growing period by about three weeks. The flowering period was thus increased by about a month. This resulted in all strains being more hard-seeded than those at Burnley, when sampled at the end of November. The hard seed percentage in plants of the nine strains, grown at Swan Hill and Burnley, are compared in Table 6.

TABLE 6.

Variation in soft seed yield a/c strain and district. Harvested end October, 1938.

Strain.	Percentage Soft Seeds.	
	Melbourne.	Swan Hill.
Dwalganup	Basal .. 47	4
	Upper .. 60	42
Mulwala	B. .. 60	17
	U. .. 70	75
Springhurst	62	B. .. 6
		U. .. 36
Bacchus Marsh	B. .. 12	12
	U. .. 60	12
Mt. Barker	72	B. .. 36
		U. .. 41
Nangeela	65	20
Burnerang	..	30
Macarthur	100	35
Tallarook	100	92

(3) *Factors Influencing Formation of Hard Seeds.*

From the foregoing observations on the occurrence of hard seeds in the plant, and in the strain, it is indicated that (1) length of development of the seed determines its capacity to become hard; (2) degree of drying influences its attainment of hardness. Experimental evidence on the importance of dehydration is summarised below.

Several workers, notably Helgeson (6) and Dutt and Thakurta (3) have noted the effect of degree of dehydration on the formation of hard seed. In both *Melilotus alba* and *Cajanus indica* it was found that where seeds which had reached maximum size were subjected to a certain amount of drying, germination could invariably ensue under favourable conditions, but on further drying, impermeability developed, which however could be reversed at once, by scarifying.

The effect of dehydration on full-sized seeds was therefore investigated, using different environments, and different times of exposure to one environment. Burrs were obtained from plants of the Dwalganup strain, which had been sown in December and had begun flowering in March. The seeds were 4 mm. long

and the testas deep red. Four quadruplicate samples of 25 were used in each of the tests in Table 7; the test begun 30th June, 1938, varied the rate of dehydration in one time; and the test begun 14th July, 1938, varied the time, the rate being constant.

TABLE 7.

Effect of dehydration on hard seed formation.

Date Commenced.	Length of Time.	Temp. Deg. Cent.	Relative Humidity.	Saturation Deficit.	Percentage Hard Seed.
			%		
30·6·38 ..	12 days ..	15	80	0·11	0
		15	0	0·54	40
		29	35	0·93	65
		29	0	1·41	75
14·7·38 ..	18 hours ..	29	0	1·41	15
	42 hours ..	29	0	1·41	17
	72 hours ..	29	0	1·41	35
	11 days ..	29	0	1·41	52

It is evident that in *Trifolium subterraneum*, the degree of dehydration controls the formation of hard seeds from previously permeable full-sized seeds. The factors in this dehydration are temperature, relative humidity, and the length of time during which they can act. The drying effect of high temperature and low relative humidity is expressed more briefly in terms of saturation deficit. It may therefore be said that the more intense the factors of saturation deficit and of time, the more hard seeds are formed in the burrs of any sufficiently mature plant.

(4) *Comparison of Hard and Soft Seeds.*

Storage in moist air will cause an obvious absorption of water on the soft type, but not on the hard which is unable to absorb water into the seed below the testa. After such a process, the hard seed will be black all over or at most, slightly pink at the hilum; the soft seed will be slightly larger, and purplish black except the area which includes the hilum, which will be distinctly pink.

Hard and soft seeds can be separated by this colour difference in samples of burr harvested later than usual in autumn after exposure to weather conditions of varying moisture since their ripening in December. This difference can also be readily observed in commercial seed stored several years under a low saturation deficit. In freshly dried burrs, however, the two types of seed are indistinguishable.

In order to determine the absorption of water vapour by hard and soft seed, samples of 200 seeds of both hard and soft types (distinguished by swelling capacity) were brought to constant weight in a desiccator and then exposed to room conditions

(70–80% R.H. and 16° C. + 2) and weighed periodically. Fig. 2 shows the results. In 30 days, the percentage increase of weight in the soft seeds was three times that in the hard. This effect is reversible.

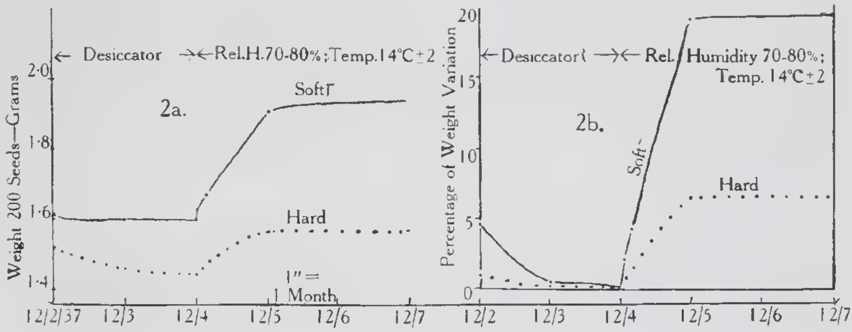


FIG. 2.—Absorption of water-vapour by hard and soft seeds; (*a*) showing relative weight changes; (*b*) showing changes in weight as a percentage of weight of each type, after two months in desiccator.

Hard seeds are evidently able to absorb some water vapour, and other tests show that water soluble dyes penetrated the matrix of hard seeds but no further, whereas they stained the whole testa in soft seeds. Since the anthocyan colour in the testa is situated below the impermeable layer, the addition of water to hard seeds might be expected to have no effect on colour, the matrix only, being affected. Conversely, the penetration of moisture in the soft seed lightens the testa colour and causes the characteristic pink appearance of the hilar region.

Soft seeds should generally be larger than hard because of their greater capacity to absorb water vapour. This was proved in a test on two-years old samples of seed, from burr collected in the field and from a commercial source. They were graded on a 2 mm. square mesh sieve, and those that passed through were put through a 2 mm. round mesh sieve. The percentages of soft seed in each grade are shown in Table 8.

TABLE 8.

Effect of seed size on soft seed percentage. (Samples of 200 seeds, each duplicated.)

Graded 2 mm. Square Mesh.	Percentage Soft.	
	Burr.	Commercial Seed.
	%	%
Graded > 2 mm. square mesh	35	94
,, < 2 mm. square mesh	14	88
,, < 2 mm. round mesh	5	79

The effect of the higher water content of the soft seed is evident in the soft seeds being about 15% heavier than the hard under ordinary storage conditions.

On a dry weight basis, however, soft seeds are about 20% lighter than hard in the same sample. Samples of 100 seeds of both hard and soft types, from single plants and bulk sources, were weighed, dried at 100° C. for four days, and weighed again. Taking one result, 100 hard seeds weighing 0.6535 grams, were dried to 0.6228 grams after a loss of 4.7% water; 100 soft seeds weighing 0.7123 grams were reduced to 0.4898 grams, after a loss of 30% water.

The higher dry matter content of the hard seed might be expected from the correlation of length of seed development with capacity for hardseededness. A long period of development should mean a high nutrient concentration and hence a high dry matter content, and the evidence supports this assumption.

The Softening of Hard Seeds, under Natural and Commercial Conditions.

The natural causes for the softening of hard seed in storage or soil are of interest to any concerned with the agricultural value of such seed. A review of the literature showed only isolated tests on single factors thought to be of importance—namely, temperature, mechanical pressure, humidity, alternation of wet and dry conditions.

Information was obtained on the occurrence of hard and soft seed in burrs harvested in March, 1936, by Mr. W. W. England, of Warncoort, Victoria, and received in May. Most of the burrs contained three or four seeds and separation of the results into those two classes showed that the percentage of soft seed in each did not differ significantly from a total of 20 per cent.

A later count of burrs containing 5, 4, 3, and 2 seeds gave similar results. There is no evidence to suggest that the occurrence of soft seed is influenced by the total number of seeds per burr. The staining of these seeds with osmic acid showed that most of the seeds which were soft, had been hard. The softening must have taken place between early January and May.

Under field conditions, burrs gave a certain percentage of soft seed at first, followed by decreasing amounts during the next months and years.

Conditions of storage affected the rate of softening in these burrs. The percentage of soft seed in burrs kept both dry, and wet occasionally, in a well-ventilated concrete building subject to daily fluctuations of 20–30°F., was significantly greater than in the rest of the burr stored in the soil laboratory with a daily

range of 2–5°F. Fig. 3 records that in the latter, even after two years, there is no significant increase from the original 20 per cent., whereas, in the former, the soft seed percentage has increased to 50 per cent. Similar burrs tested for four months under the range of conditions in Table 9 showed similar increased softening with wide daily temperature ranges.

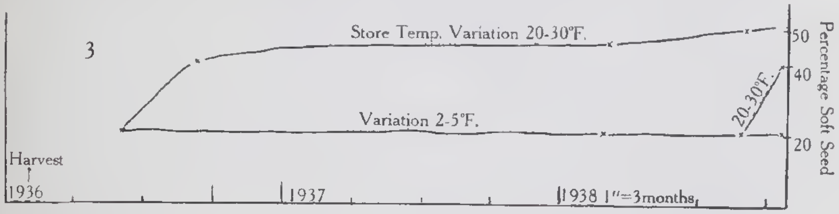


FIG. 3.—Rate of softening of seeds in burr, as affected by high and low daily ranges of temperatures.

TABLE 9.

Place.	Range of Temperatures.	Percentage of Soft Seeds after Period Aug. to Nov., 1938.
		%
Bulk store of 1938 burr ..	4° F.	18 (no increase on original test)
Oven at 29° C.	4° F.	26
Window ledge	60–110° F.	34 (distinct increase)
Buried in soil in plot ..	40–120° F.	50 (distinct increase)

From the above observations, the importance of environment on softening in soil and storage is apparent. The possible factors of this environment are temperature, humidity, soil microflora that might assist in breaking down the outer part of the seedcoat, and alternate wetting and drying.

In order to test, under conditions of favourable culture and at a constant temperature of 28°C., the effect of the main types of microflora which may occur on and around the seedcoat of hard seeds, the following experiment was carried out. Moulds were favoured on a medium of glucose agar, root nodule bacteria on yeast mannite and other possible testa saprophytes on a silica gel. Four intensities of infection were used, viz., sterilized seeds, ordinary seeds, seeds with burr debris, and seeds with soil. About 200 seeds from the Warncoort burrs were used in each dish so that the first to germinate were those already soft.

In examining the results after four months and a year's treatment in such media, the first germination (about 20 per cent.) was ignored except to find the variation and only the later germinations analysed for significance. It was found that variation between both the different types and intensities of infection was not significant after these periods.

Fig. 4, of the amount of softening in time in the three media shows how gradual the softening is. The sudden rise in the last week in May occurred after an accidental rise in temperature

to 31° and then a fall to room temperature (10–15°C.) in a week-end. Otherwise, the temperature remained at 28°C. constant throughout the test. On 28th June, 1938, the seeds were transferred to fresh media, but no marked rise followed, despite the vigorous growth of fungi and bacteria colonies.

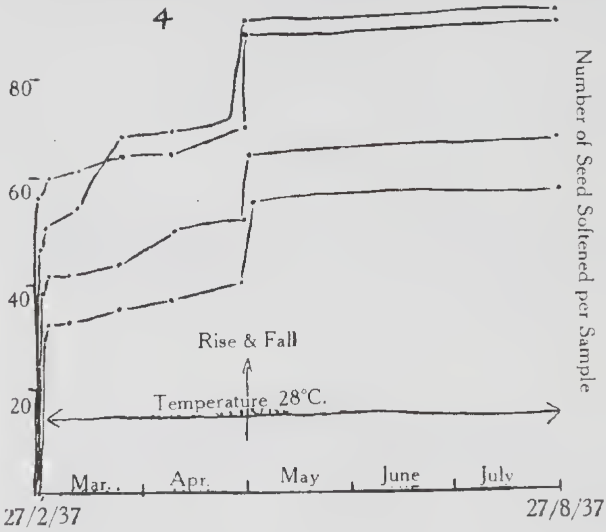


FIG. 4.—Rate of seed softening in Experiment 1 (effect of soil microflora), showing the effect of a wide temperature fluctuation.

Two strains of fat-splitting bacteria were tested on hard seeds in a broth medium, with negative results. Certain moulds and bacteria may become important after a longer period than a year but since much softening occurs within the year, the reason for this must lie with the remaining factors—temperature and moisture.

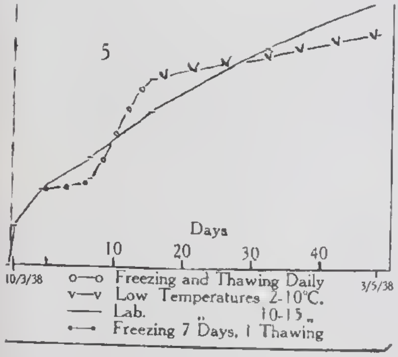
A second experiment was planned to include constant high and low temperatures and varying temperatures, with seeds continuously wet, and alternately wet and dry. In addition, seeds were tested in water changed daily, and in stagnant water contaminated with fragments of burr and hulls, and the germination was noted in burrs sown in soil in an outside plot, under normal conditions of fluctuating temperatures, moisture and microflora.

The standard error was the same as in the previous experiment, and hence the results of softening to be significant had to be more than 15 per cent. greater than the controls. Results from the 10th February to 8th April, 1937, show none significantly greater except possibly one which had been placed so as to get direct sun, and the widest temperature range possible in the laboratory (15°–40°C.). After the 8th April, it was moved out of sunshine and the softening rate became the same as most of the others.

At the end of the testing period, 8th March, 1938, the tests with two exceptions had softened about 47 per cent. The two exceptions (with 60 per cent. soft seed) had experienced the same accidental rise and fall in temperature as in the previous experiment.

These two experiments indicate that the fluctuation of temperatures is an important factor in inducing softening.

A third experiment was carried out to test the effect of freezing for seven days compared with freezing and thawing every day for seven days; and the effect of similar temperature range but not including freezing, with controls at laboratory temperature. Hard seeds of three successive harvests were used in each case, and the results showed decrease in sensitivity to temperature ranges above freezing point with increase of age. One long freezing softened the younger seeds more than the older, but a week of daily freezing and thawing to 15°C. softened a third of all the hard seeds irrespective of age. Fig. 5 shows the effect of temperature range on seed from 1937 burrs. Softening increases gradually, under 10°–15°C., while freezing over some days, or keeping at a range of 2°–10°C. retards the rate, and alternate freezing and thawing increases it conspicuously. Seed harvested in 1936 and 1935 reacted strongly to the softening effect of alternating freezing and thawing but, in contrast to 1937 seed, it was not softened at room temperatures (fig. 6).



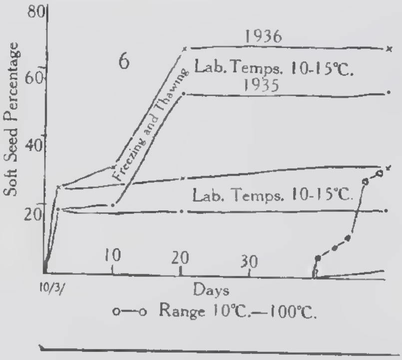


Fig. 5.—Rate of softening of seeds from 1937 burr, under various temperature ranges.

Fig. 6.—Comparison of rate of softening of seeds from burrs of 1935 and 1936 harvest, under conditions of freezing and thawing daily, for a week.

A fourth experiment was planned in order to try the effect of a wide temperature range on these less sensitive seeds. Such seeds softened considerably when subjected to such a high temperature of short duration as caused by contact with boiling water in which they are let cool. The results of repeated alternation of 10°–100° C. gave as much softening as the repeated freezing and thawing, viz. (fig. 6). The effect of a boiling water

application at night was evidenced in swollen seed the next morning.

The same result was found, though to a much less degree, with seed kept in the 28° C. incubator during the day and taken out into room temperature (10° C.) at night, as compared with no softening in seed kept constantly at 28° C.

The special effect of freezing and thawing, out of proportion to its temperature range; the increased influence of a given temperature range, the higher its mean level; and the increased softening with wider ranges and lack at constant temperatures; the modifying effect of age of hard seed on sensitivity, have all been noted experimentally. They point to the major role played by the temperature factor in the softening of hard seed under natural conditions.

It is well known that the high percentage of hard seeds usual in a burr sample of *Trifolium subterraneum* is very much reduced by the cleaning process in commercial seed production. Meadley (7) states that a variation of 14–45% soft seed in hand-cleaned samples from one small district was observed, whereas from machine-dressed lots, there was a range of 44–96%. This increase was entirely due to efficiency of the machine and the weather conditions at threshing. Hamly (4) discovered that the softening was due to the bouncing rather than to the scarifying action involved, and demonstrated in *Melilotus alba* and some clovers, the importance of an area in the seed more sensitive to stresses than elsewhere. Any break in the testa could be seen by a black stain developed with osmic acid. In the light of this knowledge, hard seeds (water tested) of subterranean clover were examined, and found to soften under the same method of shaking, after which treatment the softened ones showed the same type of staining with osmic acid, as recorded by Hamly.

Table 10 summarizes the effect of the osmic acid test on seeds after differing treatment. It confirms Hamly's results that (1) hard seeds, and soft seeds formed from hard, differ only in permeability of testa through splitting of outer cells, or by scarring by mechanical scratching. (2) That hard can be changed to soft by shaking. (3) That the area most susceptible to splitting is a special one—the strophiole. (4) That commercial seeds show far more soft seed through strophiole splitting than through external damage to the testa or because of original discontinuity of the impermeable layer round the testa. Table 11 shows the effect on softening of several mechanical methods of testa treatment, and the efficiency of the shaking or "bouncing" method.

Hence it is seen that the large increase in soft seeds found after the commercial threshing of subterranean clover burr is due to the bouncing action in the drum.

TABLE 10.

Identification of soft seed by Hamly's Osmic Acid method.

Source of Seed.	Result after five minutes in 1% Osmic Acid aq. soln.
1. Burr	Several with black spot at strophiole, and several with no marking
2. Commercial seed	Majority with black dot at strophiole, and few others with black scars elsewhere
3. Hard seed after 40 mins. conc. sulphuric acid	Black scars over testa
4. Hard seed shaken 100 times in bottle	As for (1)
5. White seed from burr ..	As for (1)

N.B.—The seeds that showed any black spot proved to be soft seed when put in water long enough to allow sufficient imbibition for swelling.

TABLE 11.

Effect of methods of Testa Abrasion on seed softening. (Duplicates of 25 burrs and 100 seeds.)

Treatment.	Per Cent. Soft Seed.
	%
1. Commercial seed	84
2. Seed from burr	20
3. Dehulled from burr	13
4. Dehulled from burr after conc. sulphuric acid for 40 minutes, but unstirred	18
5. Same, but stirred	52
6. Seed shaken 600 times in bottle	91

From the preceding information, in Sections II. and III., come the following facts:—(1) The importance of dehydration in hard seed formation; (2) prominence of fluctuating temperatures in softening hard seeds under field and storage conditions; (3) the influence of "bouncing" seed, on a special area—strophiole—during the preparation of commercial samples, in reducing the normally high hard seed content. A close examination of the seed in development and after maturity showed the internal reasons for these facts.

Relation of Seed Structure to Hardness.

So far it has been shown merely that hulled seeds are permeable to water before drying out, after which they may or may not be. Sections were taken to see the connection of the testa structure with the development of impermeability. Fig. *7a* shows the situation of the testa in a pod near full size. It was found that in later stages of the seed, the outer (Malpighian) cells went through a series of changes. At first they were colourless, and their distal ends were convex. Later a slight subcuticular layer (matrix) formed and the surface of the cell tips became flattened, then pink colour developed all through the cells. Withdrawal of the colour from the tops of the cells preceded the formation of a thicker matrix and a thin cuticle. The matrix and

decolourized cell tips appear as a lighter area above the darker cell walls beneath, without any definite translucent line at the junction. These changes in the testa, and also the accompanying crushing of the nutrient layer, and the lessening of the cell cavities after drying out, are shown in fig. 7 (*b-d*).

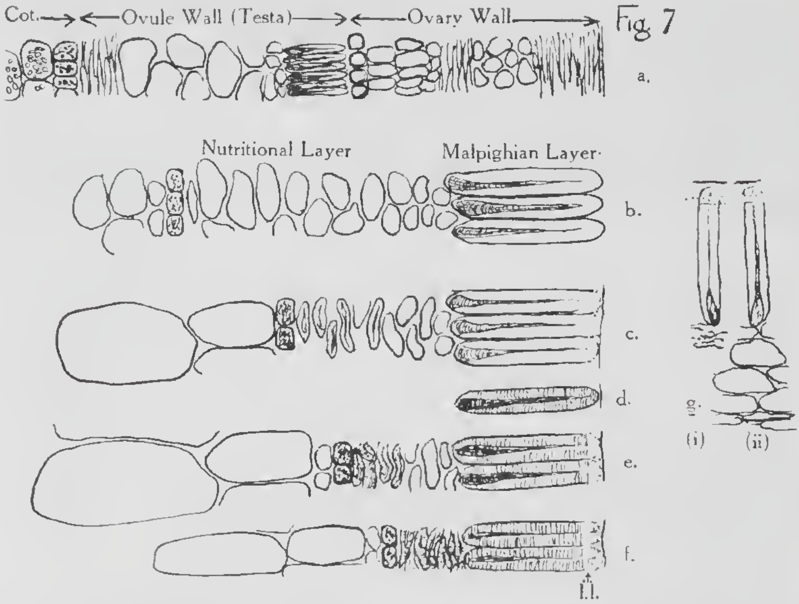


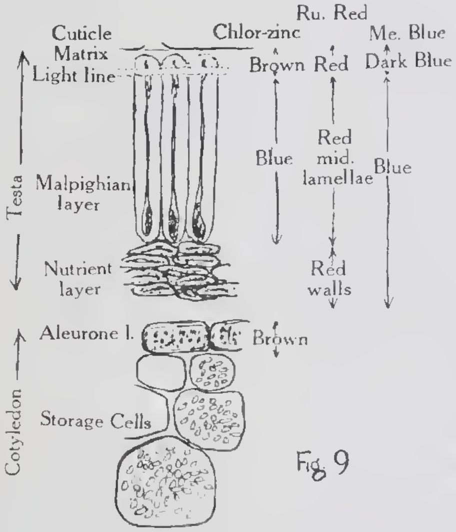
FIG. 7.—Longitudinal sections through the testa, showing (*a*) its position in the pod; (*b-f*) the changes in its cells from before the seed colours till it becomes hard; (*b*) Malpighian cells with rounded tips; (*c*) tips flattened and cuticle formed; (*d*) colour throughout cell; (*e*) colour withdrawn from tips; (*f*) reduction of cell lumens and formation of lightline, after drying of seed; (*g*) increase in depth of nutrient layer after contact with water.

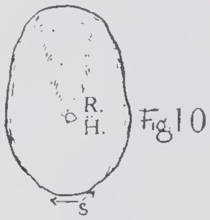
A closer study of the time of development of the light line was made using well developed seeds and varying intensities of drying. Chlorzinc iodine and safranin were used as stains to differentiate cellulose from altered substances and hand sections were made of fresh seeds. Close microscopic examination showed that at the stage when the seed was beginning to colour externally, the Malpighian cells gave an even cellulose reaction (Plate XII., A). At the stage of full development, the stain was lighter at the tips. The same staining occurred in seeds that had been dried four days but were still soft. However, in hard seeds resulting from this treatment, there was a colourless band at the top with a light line more or less in evidence at its junction with the coloured lower cells. Soft or hard seeds from commercial samples showed the same type but with the light line more conspicuous, and the matrix yellow. (Plate XII., C.)

The strophiole must be described apart from the rest of the testa for it was found that the light line appears there before the seed is fully formed. This seems linked with an earlier

development of the Malpighian cells. In seeds about 1 mm. long, the strophiole cells were three times the length of the ordinary testa cells, more vacuolated, and had less conspicuous nuclei. At 2 mm. a more or less distinct light line was evident between the lower cell walls and a definite matrix (Plate XII., B). At this stage all the testa except this area was readily permeable. It was concluded that the presence of the light line indicated that of a substance impermeable to water, and though the light line was apparent at the strophiole before dehydration of the seed, its presence throughout was necessary for impermeability.

In mature seeds both hard and soft, the testa consists of two distinct layers of cells (fig. 9). The Malpighian layer is the deeper of the two, its cells being usually 3μ in diameter, and 24μ long. The outer surface of these is covered by a thin cuticle over a substance $1–2\mu$ thick which reacts to pectin dyes but does not swell on contact with water. That water can penetrate the cuticle and matrix is shown by the staining of these by such water soluble dyes as Methylene and Nile Blues and Crystal Violet.





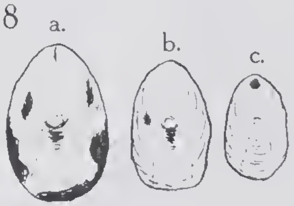


FIG. 8.—Staining reaction of seeds with osmic acid 1 per cent. for 1 minute; (*a*) at maximum size, there are scattered patches, and always at radicle tip; (*b*) dried seeds, still soft usually stain at radicle tip; (*c*) soft derived from hard develop circular stain at strophiole.

FIG. 9.—Diagram of the testa of a mature seed, with the colour reactions of some chemical tests.

FIG. 10.—Ventral view of a seed, showing hilum (*H*), radicle (*R*), and strophiole (*S*).

The walls of the upper ends of the Malpighian cells (termed "caps" by Hamly) are thickened by a material impermeable to water. This property is due to suberisation, as indicated by the cerinic acid reaction and other tests summarised in the following table, in which names at the head of columns refer to the layers in fig. 9.

TABLE 12.
Reactions of Testa.

Test.	Cuticle.	Matrix.	Suberized Layer.	Cellulose Walls.	Pectins of Nutrient Layer.
Phloroglucin and HCl. (Lignin)	..	..	..	Pink (∵ anthocyan)	
Cerinic acid (Suberin)	..	..	Yellow fat drops		
Chromic acid (Suberin)	..	..	The most resistant	Brown	
Crystal Violet (Fats)	Blue	Light violet	..	Lighter violet	
Schweitzers Reagent (Cellulose)	..	Swollen granular	..	Blue ..	Clear
Conc. H_2SO_4 and I. (Cellulose)	Dark	Dark ..	..	Mauve	Bluish to yellow walls
Chlor-zinc iodine (Cellulose)	..	..	..	Blue ..	Clear
HCl. then Amm. 2 per cent. (dissolves pectins)	..	Dissolves			
Ruthenium Red (Pectins)	..	Pink ..	..	Pink, mid lamellae	Pink
Methylene Blue (Pectins)	Violet	Bluish ..	..	Greenish	Blue

The junction between the suberised area and the unsuberised walls below is distinguishable as a translucent refractive line about 1μ thick occurring 3μ below the cuticle, and known as the "light line." The cause of this line has been shown by Hamly (4), to be due to the contact of substances of differing refractive indices.

Below the light line the walls of the Malpighian cells are of a cellulose nature, as seen from their reaction with chlorzinc iodine and sulphuric acid, but contain also certain substances that cause some reduction of osmic acid and a consequent black stain. The lumen of the cell decreases in width in the upper two-thirds of its length till it becomes about 0.3μ. Staining with osmic acid shows that several processes project vertically in the lumen just below the suberisation. In the dry seed, the cell contents are confined to a small deposit at the base of the cell, and noticeable only when stained by such as crystal violet or osmic acid. No chromatophores are visible as are characteristic of the Malpighian cells of *Albizzia*.

The inner layer of the testa consists of about five rows of dead, collapsed cells of the "nutrient layer." These have a great capacity for swelling in the presence of water, due to the

high proportion of pectin in their walls, e.f. fig. 7 *g*. In *T. subterraneum,* the osteosclerid layer, occurring between nutrient and Malpighian layers, and typically formed of hourglass cells, is not sufficiently distinct to be separated from the nutrient layer. This is an exception to the general rule established by Pammell (8) for most leguminous genera including Trifolium.

The outer tissue of the cotyledon occasionally adheres to the testa, but as it consists of a single layer of large rectangular protein rich cells covering many rows of starch filled cells increasing in diameter 5–30μ it is easily distinguishable. A small amount of endosperm residue may also be observed at times.

The typical black colour of the testa is given by a blue water soluble substance contained in the lower unsuberised portions of the Malpighian layer, and distributed especially in the cell contents. This colour is an anthocyan, as it turns red with glacial acetic acid, and is comparable to that in the coloured spots of certain seeds of *Melilotus alba*. It is sensitive to pH change, going red with acid, and blue to brown with alkali. The phloroglucin test for lignin therefore gives a positive reaction in the cell walls in which this pigment occurs, not confirmed in seeds with colourless coats. Contact with zinc causes the testa to change to green. During absorption of water in a soft seed, the dye passes out in solution through cracks in the upper parts of the Malpighian cells and stains surrounding paper or water. The loss of some of the colouring matter in this way, combined with decrease in concentration of the remainder through the increased area of the testa, causes the change from the black of a dry seed to the pink of a swollen one. A hard seed will give no stain if wet, since there is no way the dye can escape.

Investigation of the effect of wetting on the testa layers showed that the collapsed "nutrient" layer expands up to about three times its normal thickness, and the Malpighian cells by about 10%. Both layers expand this latter amount in width. The great increase in size of the nutrient layer through imbibition of water is a reversible process. This may mean that temporary wetting of soft seeds in the field may cause little damage.

The effect of water on a whole soft seed is to cause swelling in a similar way to that in a free section but the collapsed layer may not expand in depth so much. The swelling and consequent increase in volume of the testa causes a gap (demonstrable on cutting sections of freshly swollen seed). to form between it and the cotyledons within. These in turn absorb water and expand about 30% in diameter when they again fit closely to the testa till after germination.

The testas of both hard and soft seeds show the same physical and chemical organisation. Their functional difference is solely due to permeability in various localities of the soft seed. The seed that has dried out but has not become hard is permeable in one or more irregular patches over the seed coat, generally

at or near the hilum, and is termed "original" soft seed. This permeability is due to incomplete formation of the suberinogenitic layer in the cell caps of those areas, as is evidenced by the absence of the light line. Such seeds may become hard by further drying out, which induces continuity of the impermeable layer.

Hard seeds become soft as a rule in one special locality, the strophiole, which is never permeable in original soft seed. This area is located on the long end of the seed near the hilum (fig. 10) and clefts through the light line will occur after sufficient local stress, e.g., fluctuating temperatures or bouncing. Present investigations on this clover, and local samples of lucerne, strawberry clover, white and sweet clover, confirm Hamly's discovery of the structural importance of the strophiole in the softening of hard seeds. Sections show that the Malpighian cells are bent in this area, not vertical as in the rest of the testa, and are 3–4 times as long. Table 13 and fig. 11 *a b*. It was seen previously that they develop more rapidly, even forming a light line before the seed dries out. This precocity is evidently linked with increased tension between the cells with consequent greater sensitivity to splitting

TABLE 13.
Size of Testa Cells.

—	Strophiole Cells.	Ordinary Testa Cells.
1. Depth cuticle to light line	18 μ	6 μ
2. Depth cuticle base Malpighian cells	140 μ	50 μ
3. Depth nutritional layer	20 μ	10 μ
4. Width Malpighian cells	6 μ	8–10 μ

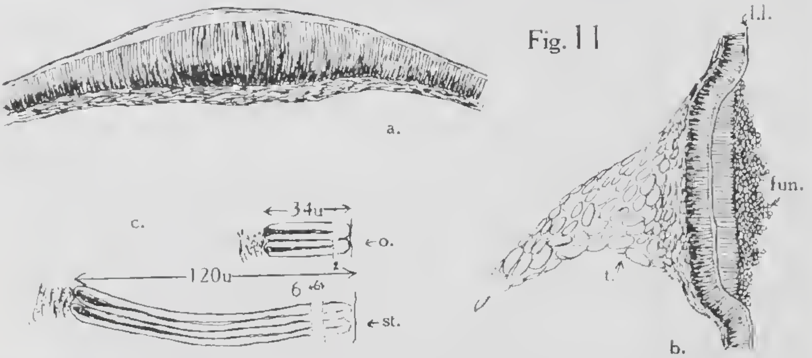


FIG. 11.—Longitudinal sections (*a*) through the strophiole of a hard seed, showing the increased size of the Malpighian cells, and their bent positions; (*b*) through the hilum, showing the continuity of the lightline, and the loose cells of the funicle, left after separation of the seed on drying; (*c*) comparison of Malpighian cells at strophiole and elsewhere in the testa. (fun. = funicular cells, l.l. = lightline, t. = tissue between radicle and cotyledons, st. = strophiole, o. = ordinary testa cells.)

than elsewhere. In Plate XII., F, the penetration of osmic acid at the strophiole of a softened seed is evident, and contrasts with that in a seed before drying (Plate XII., E).

Discussion.

The significance of hard seeds in the soil is important in all clovers and medicks, and is of special interest with reference to subterranean clover as a component of the pastures of southern Australia since this plant is an annual, depending for its persistence and spread on establishment from seed.

The plant dies at the onset of dry conditions in early summer, and if there has been successful burr production, the matured seed is capable of germination from December onwards, but only a small percentage is "soft." Heavy rain is sufficient to germinate this. But the dry weather that usually follows soon kills all or most of the seedlings. The same will occur after any further "breaks" in the hot dry conditions until with the autumn rains, a level of available moisture is reached which is adequate for establishment of seedlings. Observations show that normally there is no further germination till spring when a further burst of seedlings appears. Such irregular germinations will continue in the next years till all have softened. In some years, the first heavy rains occur in autumn, and therefore are followed by very heavy germination, and the hard seeds left, later give rise to seedlings for which there are no openings in the sward. If there are no heavy rains till winter, seedling establishment will be so poor owing to low temperatures, that further spring germination will be very useful in filling spaces in the "open" pastures.

Under some circumstances, the presence of hard seeds is an insurance, under others superfluous in the field, in others when the total number of soft seeds is small, is a definite deterrent to a quick even establishment of a thick stand.

Burial of the burr in subterranean clover has been regarded as a means of securing a larger number of soft seeds, and hence heavier seedling establishment. Present investigations have indicated that in well developed seeds, dried in the burr at the same time, those dried above ground will form a greater percentage of hard seeds, because of the higher saturation deficit; usually however, the buried seeds develop further because of a moister environment, and their later drying results in higher hardseededness, which is also generally of longer duration.

The fact of hardseededness seems to depend on a continuity of an impermeable suberinogenitic thickening with consequent evidence of a lightline, on the top of the Malpighian cells. This continuity is dependent on (1) the tendency of the cells to deposit the thickening according to an inherited capacity; (2) time for deposition; (3) degree of dehydration.

Workers with other legumes such as lupins and sweetclover. have shown the practicability of selecting more permeable seeded lines. In subterranean clover, the individual variation in hard-seededness indicates the possibility of selection here also. Stevenson (9) indicates that the more permeable strains in *Melilotus alba* are so because of lack of continuity of the suberin round the testa.

The quality of hardseededness depends on the tendency of the strophiolar cells to split. The evidence is that long development of the seed before drying out, and high degree of drying results in hard seed of long duration. It is probable from this that this splitting is a function of (1) tension between cells; (2) thickness of suberin at shoulders of cell caps; (3) degree of dehydration. Variations in this quality are the cause for the gradual softening through the years. The variability in rapidity of splitting at the strophiole under stress seems to be related more to conditions of ripening than to strain differences, and may be influenced by varying the time of flowering and ripening.

Preliminary observations have shown that reliable assessment of the establishment value of hard seeds of this clover, in Victoria, according to their germination by mid-April, and by September the next spring would be of use in the field.

This knowledge is of no importance in good quality commercial seed because of the efficiency in softening, of machine harvesting methods.

In fig. 12 the present knowledge on maturation and germinability of the seed of *T. subterraneum* is summarized. It corresponds closely to that of *Cajanus indica,* Dutt (3).

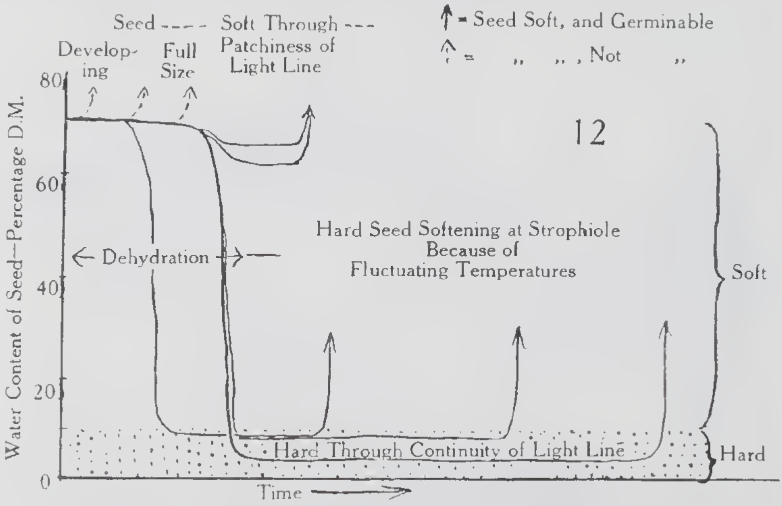


Fig. 12.—Summary of the behaviour of the seed of *Trifolium subterraneum* after growth to maximum size, indicating the relation of softness to germinability, and that of hardness to degree of dehydration, and to continuity of the lightline.

Further work may develop methods of controlling the process of seed development in a desired stage of maturity, e.g., a large percentage of original soft seeds, or of seeds capable of remaining hard for short or long periods.

Summary.

A full sized seed (not yet dried and fully mature) in the burr is always permeable over part of its surface, due to discontinuous development of the impermeable layer.

The drying out of these seeds results in some being sufficiently dried to develop a continuous layer of suberinogenitic character, and these form the "original" hard seeds in the burrs. Others, less dehydrated, remain permeable over part of the surface and form the "original" soft seeds. These may become hard on further drying.

Development of hard seeds is dependent on continuity of the suberin layer over the distal ends (caps) of the Malpighian cells of the testa. This continuity depends on degree of dehydration and thickness of deposition, which in turn are based on conditions of ripening in the burr.

The quality of the hardness, e.g., softening within a few weeks in the soil (pseudo-hardness), as compared with hardness lasting up to a year or more is controlled by the tension of the strophiole cell walls and the toughness of the suberin. These depend on rate of seed development, and degree of drying.

Hard seeds become soft through sensitivity of the strophiole cells to splitting under pressure. There is no reversion to hard on further drying, since a split between cells through the light line, once developed, is not sealed.

Softening of a hard seed through a split in the strophiole results from widely alternating temperatures or from freezing and thawing in the soil, and from the "bouncing" action in cleaning machinery.

Soft seeds from the burr differ from hard either in the presence of a split between cells at the strophiole, or in permeable patches in the rest of the testa. Those from commercial seed samples may also be caused by surface scratching.

Hard seeds are present in Victorian samples of subterranean clover burr to the extent of 55–90 per cent.; and in the commercial samples from 4–50 per cent. according to the roughness of the huller.

The percentage and quality of hard seeds produced by a plant of subterranean clover is controlled by seed development and degree of drying. The importance to these factors of time of flowering, panicle development, seed development above or below ground, time of burr drying, death of plant, time of harvesting, and individual plant variation within a strain, has been shown. It remains to get further data on the extent of softening in the first autumn, and to investigate the effect of strain apart from

time of flowering, and of selection within a strain, on the percentage and quality of hard seeds, before the practical value of field variation can be assessed.

Acknowledgments.

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Plates.

Plate XI.

(A) A small plant of subterranean clover, showing prostrate habit, and formation of burrs along the runners.

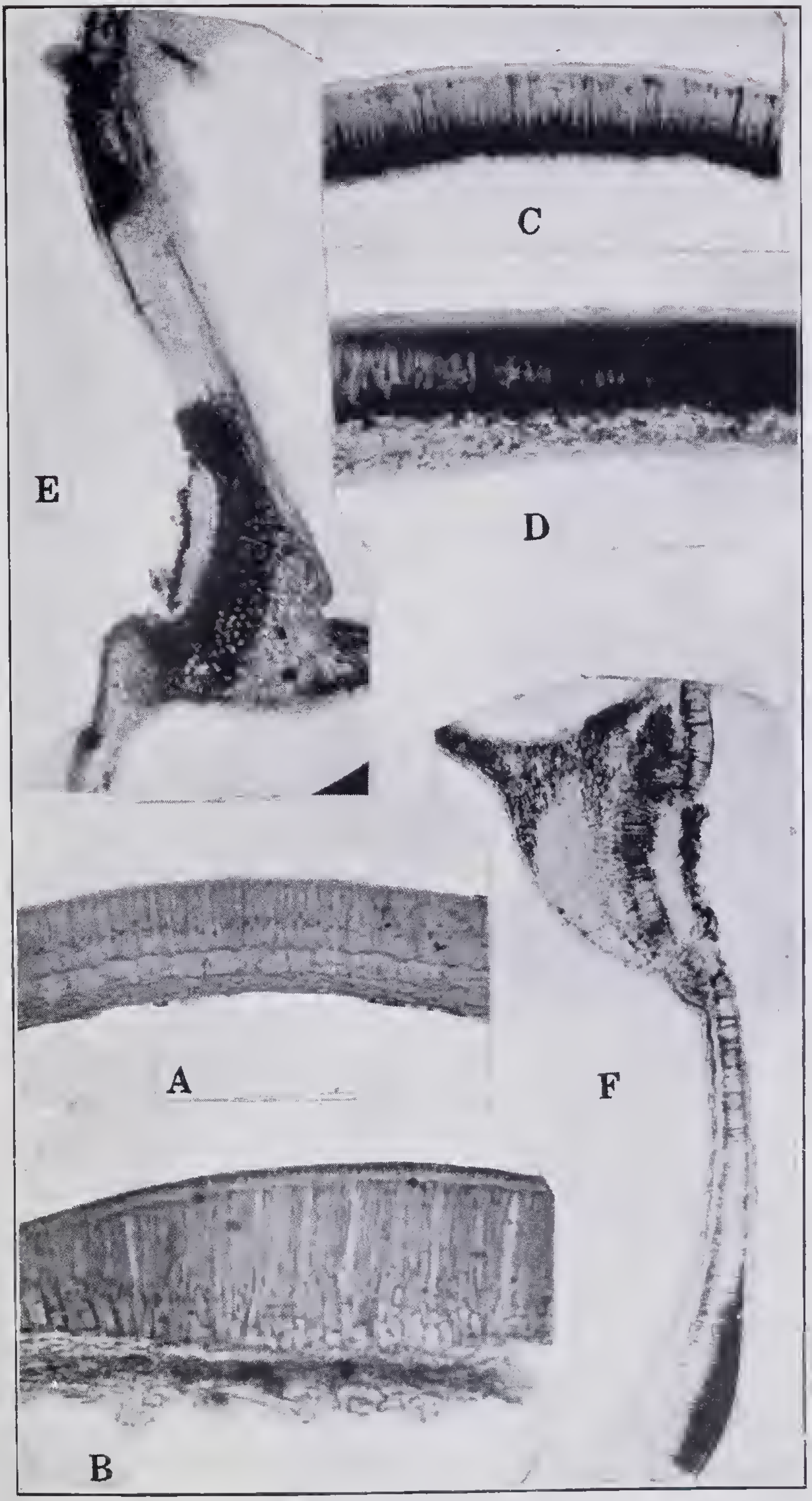
(B) Portion of a well developed runner, showing the stages from erect panicle to full grown burr.

(C) (i) Burr developed below the surface; (ii) Various views of burrs developed above ground; (iii) Pods from one burr; (iv) Full grown seeds; (v) Dried seeds.

Plate XII.

Sections: (A), through testa of half grown seed, showing nucleate, unthickened, Malpighian cells, × 250; (B), through strophiole of same, showing a conspicuous lightline, and much longer Malpighian cells, × 250; (C), through testa of a hard seed, showing development of colour (especially in the cell lumens), lightline, thickening of cells, and absence of distinct nuclei, × 250; (D), the same, with the thickness of matrix defined by the spread of osmic acid staining below the lightline from a nearby scratch, × 350; through hilum and strophiole of seeds after treatment with osmic acid; (E), in a fully developed seed, the black stain shows entry of acid round hilum, near strophiole and elsewhere, × 80; (F), in a hard seed turned soft, entry is at the strophiole only, × 80.

Aitken—Subterranean Clover.



Aitken—Subterranean Clover.

[Proc. Roy. Soc. Victoria, **51** (N.S.), Pt. II., 1939.]

Art. X.—*Additional Notes on Petaline Vestiges in Eucalyptus.*

By A. D. HARDY.

[Read 10th November, 1938; issued separately, 24th July, 1939.]

Attention was directed by the author in a paper on "Petaline Vestiges in Eucalyptus" (Rept. A.N.Z.A.A.S. XXII, p. 372, 1935) to the fact that the bud-cap or operculum in *Eucalyptus* was not always a complete, hollow cone as it was generally thought to be, but was in a transitory stage, frequently bearing indications of petaline lobing at the apex. It was noted as significant that the comparatively few species then examined were of the section Corymbosae and therefore nearest to the reputed ancestor of the genus—*Angophora*.

Since that date, many species have been under observation and the 55 now recorded include some of such diverse character and habitat that they may be taken as a fair sample of the total species of the genus. Further examination has shown that the minute lobing which can be microscopically seen in the buds of many species is a character of frequent occurrence and one which, though not essential, is still worthy of inclusion in any extended description of this genus.

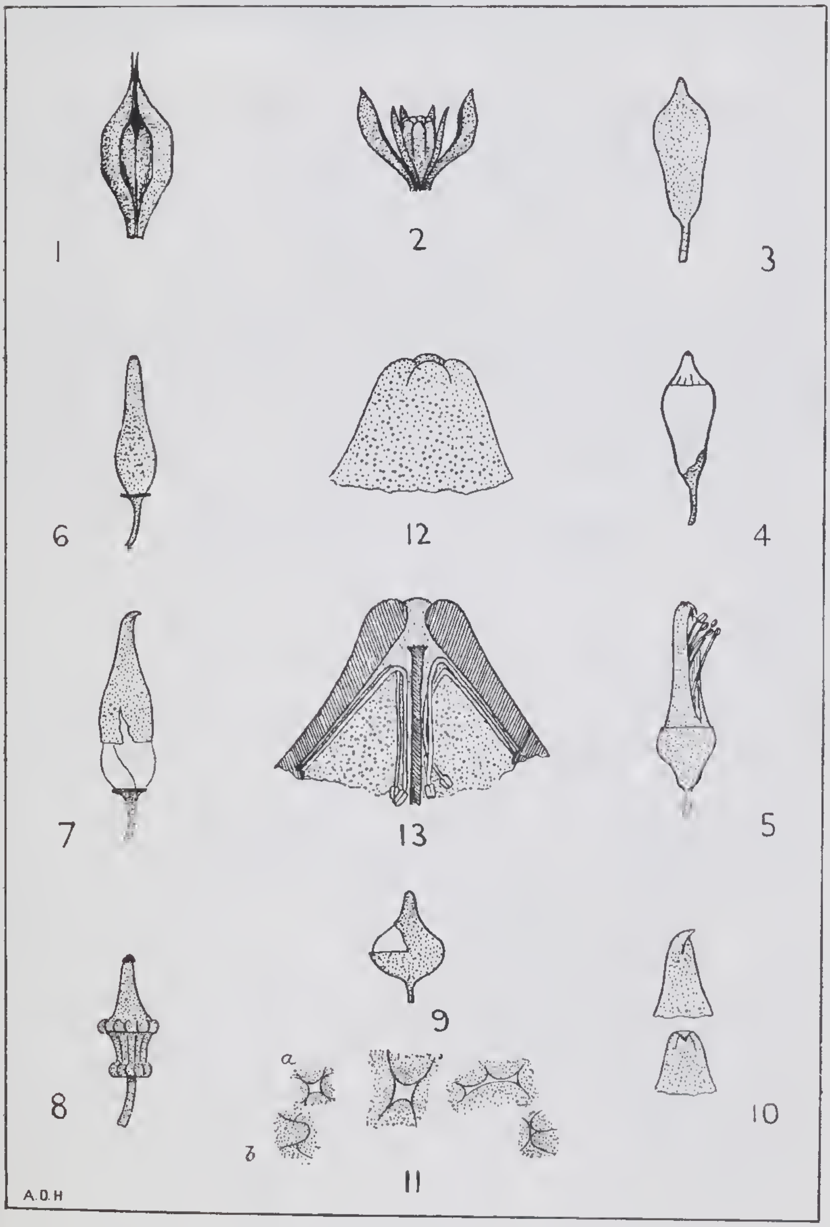
Although the lobing occurs in the same species in various localities, apparently unaffected by climate, altitude, aspect or soil, the arrangement of the lobes is as a rule irregular; the umbels on any tree may not be similarly affected nor in any umbel may the buds bear the indications equally. Macroscopically, the lobes are barely visible, the apex of the bud appearing as a rosy red point, but through a pocket lens, magnifying 10 diameters, they are seen to be a group of 2–4, rarely 5 papillae. Magnification of about 50 diameters reveals distinctly the lobes and, not infrequently, a pore (fig. 11), which communicates between the staminal chamber and the exterior. The pore may not be continuous; it may end indefinitely in the soft tissue of the bud-tip, or may be stopped by the stigma. A less common occurrence is seen in some buds of species which have a long-pointed operculum. In these, the apex may be bi-lobed, a superior lobe curving over like the upper mandible of a hawk's beak (fig. 10). This has been seen occasionally in *rostrata, leucoxylon* and *sideroxylon.* The ideal disposition is a symmetrical group of four lobes as in many young umbels of *calophylla* (figs. 12, 11A). The immature buds of calophylla (fig. 2), &c., have the apical lobing developed while still enclosed by the bracts of the umbel (fig. 1).

The fact that most of the examined opercula of matured or half-grown buds bore stomata is not enough, in itself, to decide whether the operculum is a fusion of calycine and corolline elements or is corolline only. In the absence of a calycine structure, the corolla in modified form may have learned to function as such. The scar at the base of the operculum (fig. 5, *platypus* var.), as seen in most species, is visible at a very early stage and persists till the bud's maturity, and it marks the line of circumcision whence the outer member of the modified floral envelope appears to have vanished. On many maturing buds of some species, and seen as a black spot on the apex, there appears to be the perched sepaline cap of the juvenile bud, e.g. *torquata* (fig. 8). Sometimes a portion of the epidermis is continuous from the thalamus tube, part of the way or even quite to the apex, interrupting the line of circumcision and preserving the unbroken profile curve of the bud (fig. 9, *rostrata* = *Camaldulensis*). The unbroken profile curve is a normal feature of *calophylla*, *ficifolia* (fig. 3), &c., and suggests a composite structure of the operculum in these species; but if, after maceration, the bud is skinned it sometimes appears as in fig. 4. If it were common to all species, it would make more acceptable a suggestion, made to me by the late Professor A. J. Ewart, that the lower part of the operculum might, after histological search, prove to be an extension of the thalamus tube.

If the lower part of the operculum is the concrescence of the members of a whorl, such concrescence appears to have occurred during the development of the primordial papillae.

The petaline feature described above cannot be seen satisfactorily in herbarium or shrivelled specimens. The buds must be freshly gathered, or studied on the tree (as in the present investigation with *ficifolia*, *calophylla*, *torquata*, *rostrata*, and *platypus* var., from infancy to maturity.

Something analogous can be seen in the calycine calyptra of some Papaveraceae and, of the Melastomaceae, *Pternandra cordata*. Of the former, the long calpytra of *Eschscholtzia Californica* (figs. 6, 7) is, from a basal circumcision, pushed up and off by the expanding petals, but this is frequently accompanied by a partial splitting from the base upwards. It has a minutely lobed apex in which, when bi-lobed, the "hawk-beak" arrangement occurs. In *Papaver nudicaule* var. *radicata*, there is a tendency to throw off the sepals in the form of a cap, which are often seen perched on the expanding corolla and parted at the base only. A rare occurrence in *Eucalyptus* is that which was seen in seven buds of *platypus* var. (fig. 5). In these cases, all on one tree, the buds had partly opened by a longitudinal fissure in the operculum, from a little above the base to or nearly to the apex, and through this opening a few of the crimson stamens protruded; but this may have been due to mechanical injury, as other buds were not ready for normal opening.



FIGS. 1-13.

Because of the importance of the operculum in systematic work on this genus, more interest attaches to the bud than perhaps to that of any other species. The subject seems to demand, or at least deserve more study, especially from a histological point of view.

The following species have been examined, but the extra-Victorian species have been observed only in cultivation, in Victoria. With the exception of *globulus* and *bicostata*, in which the tuberculation of the bud made observation difficult; the listed species exhibited petaline vestiges more or less distinctly. Eucalyptus: *albens, Australiana* (*radiata*, var. *australiana*, Blakely), *Bosistoana, Behriana, bicolor, botryoides, cinerea, cinerea*, var. *multiflora* (*cephalocarpa*, Blakely), *camphora, calophylla, calycogona, citriodora, cladocalyx, pauciflora, cornuta, diversicolor, dives, dumosa, elaeophora, erythronema, fastigata, gigantea, globulus, globulus*, var. *bicostata* (*bicostata*, Maiden, Blakely and Simmonds), *goniocalyx, gracilis, haemastoma, hemiphloia Muelleriana, nitens, paniculata, Preissiana, platypus* (var.), *polyanthemos, punctata, radiata, regnans, rostrata* (*Camaldulensis*, var. *brevirostris*, Dehn.), *rubida, sideroxylon, leucoxylon Smithii, stellulata*, x *Studleyensis, Stuartiana, tereticornis* (*Camaldulensis*, Dehn.), *torquata, uncinata, viminalis, viridis.*

EXPLANATION OF FIGURES.

FIG. 1.—Bracts enclosing an umbel of *Eucalyptus ficifolia.*

FIG. 2.—Young umbel emerging.

FIG. 3.—Mature bud of *E. ficifolia.* No circumcision scar.

FIG. 4.—Bud of *E. ficifolia* after maceration, showing base line of operculum.

FIG. 5.—Bud of *E. platypus* (var.). Operculum ruptured longitudinally, showing extruded stamens.

FIG. 6.—*Eschscholtzia californica*, with calycine calyptra, analogous to the caducous "outer operculum" of *Eucalyptus.*

FIG. 7.—Same, showing calyptra freed by basal circumcision; and bi-lobed at apex as occasionally seen in this species and in *Eucalyptus.*

FIG. 8.—Bud of *Euc. torquata*, nearly mature, showing the minute sepaline cap ("outer operculum") perched on apex.

FIG. 9.—*E. rostrata* (*E. camaldulensis*, var. *brevirostris*). A bud (of several seen) showing continuation of the epidermis of the thalamus tube over part of the operculum.

FIG. 10.—Bird-beaked arrangement seen in some specimens of long-pointed opercula, e.g., *E. sideroxylon, E. leucoxylon, E. oleosa, E. torquata* (cf. Fig. 7).

FIG. 11.—Diagrammatic representation of various pores seen from above: (*a*) Symmetrical arrangement as infrequently seen. (*b*) Bird-beaked apex (cf. Fig. 10).

FIG. 12.—Greatly magnified apex of operculum as seen in specimens of *E. ficifolia, E. calophylla, E. platypus* (var.), *E. rostrata, E. regnans, E. viminalis*, &c.

FIG. 13.—Long. sect. through apex of bud of *E. ficifolia*, showing pore as infrequently seen.

[Proc. Roy. Soc. Victoria, **51** (N.S.), Pt. II., 1939.]

Art. XI.—*The Devonian Rugose Corals of Lilydale and Loyola, Victoria.*

By DOROTHY HILL, M.Sc. (Qld.), Ph.D. (Cantab.).

[Read 10th November, 1938; issued separately, 24th July, 1939.]

(Plates XIII–XVI.)

Summary.

In this paper the Rugosa of Lilydale and Loyola are described and figured, and a review is given of the genera and families to which they are assigned. Remarks on new septal structures are included. Both faunas, previously supposed Upper Silurian, are shown to be Devonian; that of Loyola is probably Lower Devonian, and that of Lilydale older than Upper Devonian.

The Faunas and their Ages.

Corals have been known from Lilydale since 1890, when Etheridge described *Favosites grandipora*, referring to the age as Upper Silurian. The Rugosa from Lilydale have been described by Chapman (1914, 1925, 1931). Rugosa from Loyola were first described by Dun (1898), later by Etheridge (1899) and Chapman (1914) as Upper Silurian. An investigation of the stromatoporoid faunas of Lilydale and Loyola has suggested to Miss Ripper (1933, 1937 *a*, *b*, 1938) that both are Devonian (1938, p. 241); at Lilydale there is a high proportion of Lower and Middle Devonian species, but the Loyola fauna has Silurian affinities. The present study of the Rugose coral faunas indicates that both are Devonian; that of Loyola is probably Lower Devonian, and that of Lilydale either Lower or Middle Devonian. All the genera involved are characteristic of the Devonian; none has clear Silurian affinities. This determination of the age was made possible by recent work in Europe, notably by Lang and Smith, and Wedekind (see bibliography). For the purposes of the investigation all available figures of the species of the genera involved and of those genera which appear to be related have been studied, and the results of this study are included in the remarks on families and genera. The Tabulate corals are at present being investigated by O. A. Jones and myself, and so far support the conclusions expressed above

The Rugosa from Lilydale are:—

Prismatophyllum chalkii (Chapman).
Prismatophyllum stevensi (Chapman).
Mictophyllum cresswelli (Chapman).
Lyrielasma subcaespitosum (Chapman).

Prismatophyllum and *Mictophyllum* are known elsewhere only from the Devonian. *Lyriclasma* is a new genus with affinities to Lower and Middle Devonian species. From these Rugosa it is difficult to give a more precise age to the Lilydale limestone than Devonian, as none of the species show very close similarity to species known overseas. The presence of *Heliolites*, however, indicates that the fauna is older than Upper Devonian. None of the species occurs in either the Upper Silurian coral faunas of Yass, New South Wales, or the Middle Devonian fauna of Buchan, Victoria, but *L. subcaespitosum* is found at Loyola. The Lilydale coral locality is the quarry at Cave Hill.

The Rugosa from LOYOLA are :—

Acanthophyllum mansfieldense (Dun).
Phillipsastraea speciosa Chapman.
Phillipsastraea sp. indet.
Trapezophyllum elegantulum (Dun).
Thamnophyllum reclinatum sp. nov.
Loyolophyllum cresswelli Chapman.
Lyriclasma subcaespitosum (Chapman).
"*Cystiphyllum*" sp.

Acanthophyllum and *Thamnophyllum* are known only from the Devonian, *Phillipsastraea* is predominantly Devonian although two species have been recorded from the Silurian. *Trapezophyllum* and *Loyolophyllum* are found only at Loyola, but the former has affinities to the Devonian *Disphyllum* (*Phacellophyllum*), and the latter to the Devonian *Fasciphyllum* Schlüter. *Lyriclasma* occurs elsewhere at Lilydale, and cystimorphs are either Silurian or Devonian. It seems clear that this fauna is Devonian. The species *A. mansfieldense* and *T. reclinatum* are very similar to Lower Devonian species from Bohemia, and it is probable therefore that the Loyola fauna is Lower Devonian. *L. subcaespitosum* occurs at Lilydale, and *T. reclinatum* is very similar to *T. mitchellensis* (Etheridge) from Sandy's Creek, on the Mitchell River, Victoria, a locality formerly thought to be Upper Silurian, but I consider both these species indicate the Devonian. None of the other species are known elsewhere in Australia, from either the Upper Silurian Yass beds, or the Middle Devonian of Buchan or Taemas.

Family ACANTHOPHYLLIDAE.

Type Genus: ACANTHOPHYLLUM Dybowski.

Simple Rugosa with a wide dissepimentarium of small, highly arched dissepiments, long septa frequently modified, and numerous, shallowy concave tabulae deepened at the axis. The major septa are unequal, but are never amplexoid, and a metaseptum is the longest.

RANGE.—In Europe the family occurs somewhat rarely in the Lower Devonian, is very common in the Middle Devonian, and rare or absent in the Upper Devonian. There are many undescribed species in the Devonian of Australia. In the Downtonian of Russia, *Neocystiphyllum keyserlingi* (Dybowski; Soschkina, 1937, pl. xix, figs. 3, 4) may be a representative. Its apparent absence from America and Asia is surprising.

REMARKS.—This family comprises those forms related to *Cyathophyllum heterophyllum* Edwards and Haime. It is extremely difficult to decide whether the group is best divided into genera, or into sub-genera, or treated as one genus; or even on the limits of species within the group. Wedekind and others at Marburg have included German Middle Devonian members of the group under the following generic or sub-generic names:—*Mesophylloides* Wedekind (1921, p. 51), *Ptenophyllum* Wedekind (1924, p. 36), *Astrophyllum* Wedekind (1924, p. 46), *Rhopalophyllum* Wedekind (1924, p. 52), *Stenophyllum* Amanshauser in Wedekind (1925, p. 9, genotype *S. diluvianum* Amanshauser), and *Neostringophyllum* Wedekind (1921, p. 16, genotpye *N. ultimum* Wedekind). To evaluate these genera and their species in relation to one another and to the genera and species founded earlier from the same fauna would require a new revision of the German Middle Devonian Rugosa, and this of course could only be undertaken by someone to whom all the types are available. Meanwhile I refer to *Acanthophyllum* Dybowski all forms which I consider to belong to the group, *Acanthophyllum* being the earliest generic name specially applied to any of its members—viz., *Cyathophyllum heterophyllum* Edwards and Haime, and leave unsolved the taxonomic problems created by Wedekind's insufficient study of prior species and genera.

The following figures of Lower Devonian species appear to me to indicate membership of the family:—*Cyathophyllum* cf. *heterophyllum* E. & H., Charlesworth, 1914, pl. xxxi, fig. 6, Eastern Alps; *Pseudochonophyllum pseudohelianthoides* Scherzer, Sochkina, 1937, pl. xviii, figs. 1–4, Urals; *Cyathophyllum baculoides* Barrande, Počta, 1902, pl. 104, fig. 5, Koněprus, Bohemia, and Le Maitre, 1934, pl. v., fig. 18, Chalonnes, France; *Cyathophyllum ungeri* Penecke, 1894, p. viii, figs. 9–10, Graz, Austria.

Most of the Middle Devonian specimens figured by authors as *Cyathophyllum heterophyllum* and *C. torquatum* belong to the group, as also those figured by Wedekind under the generic and sub-generic names listed above. In addition, the following figures probably represent the group:—*Hallia pengellyi* Edwards and Haime, 1853, pl. xlix, fig. 6, Torquay; *Cyathophyllum obtortum* Edwards and Haime, 1853, pl. xlix, fig. 7, Torquay, and *Cyathophyllum roemeri* Edwards and Haime, 1853, pl. l, fig. 3, Torquay.

I have not seen any figures of specimens from the Upper Devonian which could represent members of the family.

Genus ACANTHOPHYLLUM Dybowski.

Acanthophyllum Dybowski, 1873, p. 339; 1874, p. 493.

Rhopalophyllum Wedekind, 1924, p. 52.

Genosyntypes: Cyathophyllum heterophyllum Edwards and Haime, 1851, pl. x, figs. 1*a–c*. Devonian, Eifel.

Acanthophyllum linarsönii Dybowski, 1874, p. 493, pl. v, figs. 1–1*a*, Silurian, Insel Oesel. [possibly = *Spongophylloides* sp.]

GENOLECTOTYPE.—Chosen Schlüter, 1889, p. 38: *Cyathophyllum heterophyllum* Edwards and Haime.

DIAGNOSIS.—Large, simple Rugosa with a wide dissepimentarium of small, highly arched dissepiments, with shallowly concave, axially deepened tabulae, and with long, but unequal major septa. The axial ends of the major septa are arranged in groups in the tabularium, and are straight, or curved vortically, the curvature differing in degree from group to group; the cardinal septum is typically short, and one septum, not a protoseptum, extends to the axis. The septa show different types of modification; they are frequently much dilated, either in the dissepimentarium, or more rarely in the tabularium, or in both; towards the periphery they may be thin and lined with lateral dissepiments; in the tabularium they are sometimes waved and carinate.

RANGE.—Fairly common in the Lower Devonian of Europe, and very common in the Middle Devonian of Europe. Lower and Middle Devonian of Victoria.

REMARKS.—I have examined Edwards and Haime's figured syntype of *C. heterophyllum*, now in the Natural History Museum, Paris. The unpolished vertical section shows concave, axially deepened tabulae, small, arched dissepiments, and vertical sections of the axial ends of the septa with the waves and carinae characteristic of the specimens figured by Wedekind (1924, figs. 76-98) as *Rhopalophyllum*. The major septa are more dilated than the minor septa, and both orders attenuate towards periphery and axis. A transverse section of this syntype was not available, but I consider the vertical section is sufficient to prove its identity with the *Cyathophyllum heterophyllum* E. & H. of Frech (1886, pl. vi, fig. 7), from the Upper *Calceola* beds of Auburg near Gerolstein, which was refigured by Wedekind (1924, fig. 96) as a syntype of his new sub-genus *Rhopalophyllum* of his new genus *Ptenophyllum*. By my here chosing *C. heterophyllum* E. & H., Frech as genolectotype of *Rhopalophyllum*, *Rhopalophyllum* becomes a synonym of *Acanthophyllum*. Other genera described by Wedekind under his family Ptenophyllidae may well be synonyms of *Acanthophyllum* (see remarks on the Family Acanthophyllidae).

ACANTHOPHYLLUM MANSFIELDENSE (Dun).

(Plate XV, figs. 1–3.)

Cyathophyllum mansfieldense Dun, 1898, p. 87, pl. iii, figs. 3–4; Griffith's Quarry, Loyola, near Mansfield.

HOLOTYPE.—George Sweet Collection, National Museum, Melbourne.

DIAGNOSIS.—*Acanthophyllum* with septa carinate and but slightly curved in the dissepimentarium, the dilatation periodically increasing wedge-wise towards the periphery and then being suddenly reduced.

DESCRIPTION.—This description is based on two fragments collected by Miss E. Ripper, 1646 and 1653 in the Department of Geology, Melbourne University. The first has a diameter of 38 mm., and the second of 15 mm. From these it is inferred that the corallum is simple, and turbinate or trochoid. There are 52 septa, the 26 minor septa being equal in length and extending three-quarters of the way to the axis. The major septa extend unequally into the tabularium; the cardinal septum is the shortest, and none of the proto-septa are predominant in length, the longest septum being a meta-septum in one of the cardinal quadrants. Those parts of the septa in the tabularium may be straight, or turned aside at their axial edges, and waved or carinate, and sometimes swollen slightly at the axial edge; dilatation is not great. Those parts of the septa in the dissepimentarium are dilated, and in transverse section the dilitation would appear to be periodic. Thus the septa thicken outwards like wedges for some distance, when there is a general and sudden reduction, so that wide interseptal loculi appear; then again they thicken outwards wedgewise, and again a sudden reduction occurs. Thus successive but rather irregular stereozones are obtained. The septa are dilated and in contact at the periphery. The fibres of the septal trabeculae are directed obliquely from the median plane of the septum. The floor of the tabularium is slightly concave, with an axial deepening; the tabellae are incomplete, closely placed and shallowly arched. The dissepiments are small and rather highly arched, numerous, slightly inclined at the periphery, but becoming steeply inclined near the tabularium, and are frequently of angular transverse section.

REMARKS.—In the nature of the dilatation of its septa, this species is exactly similar to *Acanthophyllum baculoides* (Barrande in Počta, 1902, pl. 104, fig. 5) from F_2 (Coblenzian), Koněprus, Bohemia, and from the limestone of Chalonnes, France, which Le Maitre (1934) has argued is at the limit between the Coblenzian (top of the Lower Devonian) and Couvinian (base of the Middle Devonian). But *A. baculoides* in contrast to *A. mansfieldense,* shows marked rotation of the septa in the tabularium. *A. baculoides* and *A. mansfieldense* have

a different type of septal dilatation from all other *Acanthophyllum*, in that the septa increase in thickness wedgewise to the periphery, with or without intermittent setbacks; in most *Acanthophyllum* the septa are spindled, dilatation decreasing towards the periphery as well as towards the axis. Connected with these two types of dilatation is the appearance of two types of dissepiment-like plates derived from the septal invaginations. In *A. baculoides* where the dilatation increases towards the periphery, the septa may break down into naic plates (Hill, 1935, p. 502); in *A. richteri* (Wedekind, 1921, pl. i, fig. 2) etc. they are lined with lateral dissepiments.

Family DISPHYLLIDAE.

Type Genus: DISPHYLLUM de Fromentel, 1861, p. 302.

Rugose corals with septa which tend to be dilated and to develop trabecular carinae, and to have an area of divergence of the septal trabeculae; with flat or gently curved axial tabulae, usually complete, often supplemented by inclined, periaxial tabulae; and with globose dissepiments which may be arranged in a vertical series of horse-shoes to form the wall of the tabularium.

Range.—Devonian of Europe, America, Australia, and Asia.

REMARKS.

I.—GENERAL.

The group has been admirably expounded by Lang and Smith (1935*b*) who have recognized five genera and discussed twenty of their synonyms, including one genomorph. The phaceloid *Disphyllum* persists throughout the Devonian, showing a great variety of structure, and its genomorph {*Phacellophyllum*} Gürich (1909, p. 102) also. The phaceloid *Thamnophyllum* Penecke (1894, p. 593) is common in the Lower Devonian and Couvinian of Styria. The cerioid *Prismatophyllum* (Simpson, 1900, p. 218) occurs first in the Lower Devonian, but is more common in the Middle and Upper Devonian. The plocoid *Phillipsastraea* d'Orbigny (1849, p. 12) has been recorded from the Upper Silurian of Estonia (see p. 236). A Lower Devonian species from Bohemia was called *Phillipsastraea* by Počta (1902, p. 158), but the genus had a widespread development in the Middle and Upper Devonian. *Macgeea* Webster (1889, p. 710), a genus of solitary or weakly compound species, is known at present only from the Givetian and Frasnian. A sixth genus is here included, the cerioid *Trapezophyllum* Etheridge (1899, p. 32) from the Lower(?) Devonian of Victoria, which has the same morphological relation to *Prismatophyllum* as {*Phacellophyllum*} has to *Disphyllum*.

The Disphyllidae are extremely important in Australian Devonian faunas, and in order to facilitate comparison of the Australian species with those from known horizons overseas, and thus to ascertain their stratigraphical value, the family is reviewed in this paper. *Disphyllum* and *Macgeea* are discussed immediately, but *Thamnophyllum, Prismatophyllum, Trapezophyllum* and *Phillipsastraea* all have species occurring at Lilydale or Loyola, and are discussed under their separate generic headings.

II.—MORPHOLOGY AND STRATIGRAPHY OF DISPHYLLUM.

A.—TABULARIUM.

The arrangement of the plates in the tabularium is very varied, and six patterns are recognized. Their relation is proved by more than one of them occurring in the same corallum, and by their association with similar septal and dissepimental characters.

1. In the American Couvinian *panicum* (Winchell, Ehlers and White, 1932, p. 93, pl. i, fig. 1, pl. iii, figs. 3–5, pl. iv, figs. 3–4, pl. v) there is an inner series of unequal tabulae, sometimes complete and horizontal, domed or saucered, and an outer series of tabellae inclined towards the axis. In the co-existent *elongatum* (Simpson, 1900, fig. 42) the outer series is unimportant.

2. In the European Givetian and Frasnian *goldfussi* (Geinitz, Lang and Smith 1935*b*, pl. xxxv, figs. 4, 8) and *caespitosum* (Goldfuss, Lang and Smith, 1935*b*, p. 573) there is an inner zone of very shallowly domed plates, and a narrower outer area of large inclined plates, the outer zone forming a higher part of the calicular floor than the inner.

3. In the European Givetian and Frasnian *trigemme* (Quenstedt, Lang and Smith, 1935*b*, p. 575) this second type is modified so that the plates of the inner area are flat.

4. In the European Upper Givetian or Lower Frasnian *aequiseptatum* (Edwards and Haime, Lang and Smith, 1935*b*, pl. xxxv, fig. 14) the inner series is of incomplete unequal, but rather globose plates inclined towards the axis. The Australian *virgatum* (Hinde, Hill 1936*b*, pl. i, fig. 3) and *depressum* (Hinde, Hill, 1936*b*, pl. i, figs. 4, 7) of similar age belong to this group.

5. In the European Givetian *geinitzi* Lang and Smith, (1936*b*, pl. xxxvi, fig. 3) the outer series is not developed, and the complete tabulae are shallow domes.

6. In the European Frasnian *minus* (Roemer, Lang and Smith, 1936*b*, pl. xxxv, fig. 3, Ma 1937, pl. ii, fig. 1) the outer series becomes unimportant, and an axial series of flatly domed tabellae is superimposed on the inner series of the *goldfussi* type.

B.—Dissepimentarium.

1. In the American Couvinian *arundinaceum* (Billings, Lang and Smith, 1936*b*, p. 561) the interseptal loculi are closed by septal dilatation, except for the spaces within a single series of horse-shoe dissepiments.

2. In the American Couvinian *panicum* and *elongatum*, and the European Givetian and Frasnian *goldfussi*, the dissepiments are globose and inclined towards the axis, the inner series being more inclined than the outer, which also tend to be larger.

3. In the European Givetian and Frasnian *Phacellophyllum caespitosum* and *Phacellophyllum trigemme* there is a single outer series of flat dissepiments and a single inner series of horse-shoe dissepiments.

4. In the European Frasnian *minus* there is only a series of horse-shoe dissepiments.

5. In the European Givetian *geinitzi* there is one or sometimes two series of rather globose or highly inclined dissepiments.

C.—Septa.

1. In the American Couvinian *arundinaceum* the septa are much dilated, the dilatation decreasing sharply in the tabularium.

2. In the American Couvinian *arundinaceum* and *panicum* the septa have trabecular carinae, curved at right angles to the dissepiments.

3. In the European Givetian and Frasnian *caespitosum*, *trigemme* and *minus* the septa have trabecular expansions over the horse-shoe dissepiments, the curvature of the trabeculae being at right angles to the surfaces of the horse-shoes.

4. In the Australian Upper Givetian or Frasnian *depressum* and *virgatum*, the septa are dilated and in contact at the periphery, and through most of the dissepimentarium, but attenuate towards the axis.

5. In the European Givetian and Frasnian *goldfussi* and *aequiseptatum*, the septa are but slightly thickened, more so towards the periphery, and may be slightly sinuous.

III.—MACGEEA.

Macgeea has a type of septal dilatation (Lang and Smith, 1935*b*, p. 577) not seen in *Disphyllum*, but relationship is proved by the area of divergence in the septal trabeculae corresponding in position with the horse-shoe dissepiments (*loc. cit.* pl. xxxvii, figs. 8, 9), by the dissepimentarium, which resembles that of *Phacellophyllum*, and by the tabularium, which is a modification of the *minus* and *aequiseptatum* types.

Genus THAMNOPHYLLUM Penecke.

Thamnophyllum Penecke, 1894, p. 593.

Thamnophyllum; Lang and Smith, 1935*b*, p. 564.

GENOLECTOTYPE.—Chosen Lang and Smith *loc. cit.: Thamnophyllum stachei* Hornes in Penecke, 1894, p. 594, pl. viii, figs. 1–3, pl. xi, figs. 1–2. *Barrandei* beds (upper part of Lower Devonian) and Couvinian of Graz, Austria.

DIAGNOSIS.—Dendroid Rugosa with typically straight corallites, and increase which is usually parricidal and produces four large marginal offsets which, in their earliest stages, are united by dissepimental tissue occupying the fork formed by the diverging branches. The septa are so dilated in the dissepimentarium that the only loculi are those enclosed by a median series of horse-shoe dissepiments, the trabecular dilatation of the septa being continuous over the surfaces of these dissepiments. In the tabularium the septa are attenuate and do not reach the axis. Typically the tabulae are transverse, flat or slightly domed or saucered, mostly complete, and usually very widely spaced.

RANGE.—Upper part of the Lower Devonian of Austria, Lower Middle Devonian of Austria and France, and possibly Givetian of France.

REMARKS.—The genus differs from *Disphyllum* in the excessive septal dilatation in the dissepimentarium and in the wide spacing of its tabulae. Lang and Smith have considered it wise to regard the group as a separate genus from *Disphyllum*, and their classification is followed herein. From the American Couvinian *Synaptophyllum* Simpson (1900, p. 202) which Lang and Smith (1935*b*, p. 561) consider synonymous with *Disphyllum*, it differs only in growth form and in the absence of carination on the septa. Of the three European species recognized, the genotype has short septa, complete, widely separated tabulae, and dissepiments suppressed by the septal dilatation; *hornesi* Penecke (1894, p. 595, pl. vii, figs. 13, 14; pl. xi, fig. 3) which occurs with *stachei*, differs in having stouter corallites, longer septa, concave and less regular tabulae, and dissepiments which are not entirely masked by stereome; *murchisoni* Penecke (1894, p. 595, pl. vii, figs. 15-17) has long septa which are peripherally strongly dilated and more or less contiguous laterally, crowded tabulae, and dissepiments almost or completely masked by septal dilatation; it occurs in the Lower Devonian of Austria, and specimens from the Givetian of France have been referred to it by Le Maitre (1937, p. 111, pl. vii, figs. 3-5, 11, 12; pl. viii, fig. 7). These, however, may be *Columnaria* cf. *rhenana* Frech.

In *Thamnophyllum,* as Weissermel (1938, p. 67) has remarked, no epitheca has been observed, and the peripheral stereozone is formed entirely by the dilated septa without any circumferential wall of fibres to the interseptal loculi.

Thamnophyllum reclinatum sp. nov.

(Plate XVI, figs. 7, 8.)

Holotype.—R25186, British Museum (Natural History), London. E. O. Teale Collection, from Griffith's Limestone Quarries, S.W. from Mansfield, Victoria.

Diagnosis.—*Thamnophyllum* with major and minor septa approximately equal in length, with a wide peripheral stereozone of reclined trabeculae, a narrow tabularium, and a series of small horse-shoe dissepiments sometimes supplemented by other steeply inclined globose dissepiments.

Description.—The corallum is dendroid, the corallites being stick-like, from 3 to 5 mm. in diameter, and irregularly spaced, up to 5 mm. apart. No trace of an epitheca is seen on the corallites, the septa projecting outwards as angular ridges. The septa are of two orders, 14 to 16 of each, and the major septa can only with difficulty be distinguished from the minor, both extending about two-thirds of the way to the axis. They are dilated, particularly in the peripheral half of their length, where they are invariably in contact laterally; narrow interseptal loculi appear between the more axial parts. The septa consist of trabeculae arranged in single series, inclined fan-wise, the inclination being at right-angles to that part of the surface of the horse-shoe dissepiment on which they appear to be based; in the peripheral half of the dissepimentarium, outside the horse-shoe dissepiments, this inclination is horizontal. One series of small horse-shoe dissepiments appears in the axial parts of the dissepimentarium; it may be supplemented by an outer series of small, globose, but highly inclined plates. The tabulae are complete or incomplete, supplemented at their margins by smaller plates. They may be flat or sagging, and are rather distant.

Remarks.—This species resembles *Thamnophyllum mitchellensis* (Etheridge, 1899, p. 30, pl. A, figs. 6, 7, 8, 12; pl. B, fig. 11) from Sandy's Creek on the Mitchell River, Victoria, in the equality in length of the two orders of septa; it differs in the relative width of the dissepimentarium, which is only half the radius of the corallite in *mitchellensis,* in the width of the peripheral stereozone of inclined trabeculae, which is not noticeable in *mitchellensis,* and in the frequent occurrence of more than one series of dissepiments. It differs from all the Austrian species described by Penecke (1894) from the Lower Devonian *barrandei*-beds of Graz, Austria, in having its two orders of septa approximately equal in length. The known range of the genus in Europe is Upper Lower Devonian, and Lower Middle Devonian, and probably the Victorian species are within these age limits.

Genus PRISMATOPHYLLUM Simpson.

Prismatophyllum Simpson, 1900, p. 218.

Prismatophyllum; Lang and Smith 1935*b*, p. 558, q.v. for synonymy.

GENOTYPE.—*Prismatophyllum prisma* Lang and Smith *loc. cit.* (= *Cyathophyllum rugosum* Edwards and Haime *non* Hall. See Lang and Smith *loc. cit.*) Lower Middle Devonian Onondaga ("Jeffersonville") Limestone; Falls of Ohio, etc., U.S.A.

DIAGNOSIS.—Cerioid Rugose corals with septa which may, or may not, reach the axis; tabulae typically differentiated into a horizontally disposed axial series and an axially inclined peri-axial series; and typically numerous, small, globose dissepiments.

RANGE.—*Prismatophyllum* is rare in the Lower Devonian of France, common in the Couvinian of America and the Couvinian and Givetian of Europe, occurs rarely in the Givetian or Frasnian of Western Australia, and is common in the Frasnian of Europe and America. It has been doubtfully recorded from the Middle Devonian of China, and Yü has placed in it specimens believed to come from Lower Carboniferous rocks in China (Yü, 1933, p. 78).

REMARKS.—The cerioid *Prismatophyllum* shows certain differences from the phaceloid *Disphyllum* in the variability of its internal structure. Thus only two types of dissepimentarium are seen—the *goldfussi* type (p. 226) and a type not known in *Disphyllum,* but common in *Phillipsastraea.* A tabularium found in *Prismatophyllum* but not in *Disphyllum* (unless *Pexiphyllum arcuatum* and *ultimum* of Walther, 1928, figs. 24-26, be *Disphyllum*) is the clisioid axial structure. Spindle septa are common in *Prismatophyllum,* but rare in *Disphyllum.*

MORPHOLOGY AND STRATIGRAPHY OF *Prismatophyllum.*—I consider that the following illustrations represent *Prismatophyllum.* The list obviates the necessity to give references in the discussion following.

LOWER DEVONIAN OF FRANCE.

Acervularia namnetensis Barrois, 1889, pl. i, fig. 1.

Acervularia venetensis Barrois, 1889, pl. i, fig. 2.

COUVINIAN OF AMERICA.

Prismatophyllum anna (Whitfield); Stewart, 1938, pl. 9, figs. 11, 12.

Prismatophyllum prisma Lang and Smith; Stewart, *id.*, figs. 13–15.

Prismatophyllum whitfieldi Stewart (*non* Webster and Fenton), *id.*, pl. 10, figs. 3–4. ? = *Prismatophyllum rugosum* Simpson, 1900, figs. 44, 45; *non* Hall, *non* Edwards and Haime. ? = *Prismatophyllum goldfussi* (Edwards and Haime); Ma, 1937, pl. iii, fig. 2.

Prismatophyllum truncatum Stewart, 1938, pl. 10, figs. 1, 2.

Prismatophyllum kirki Stumm, 1937, pl. 55, fig. 7.

Prismatophyllum sedgwicki (Edwards and Haime); Ma, 1837, pl. iii, fig. 3 (Middle Devonian).

GIVETIAN OF EUROPE.

Prismatophyllum quadrigeminum (Goldfuss); Lang and Smith, 1935*a*, pl. xii, figs. 5, 6.

Prismatophyllum hexagonum (Goldfuss); Lang and Smith, 1935*a*, p. 432.

Cyathophyllum hexagonum Goldfuss; Frech, 1886, pl. iii, figs. 20–22.

Campophyllum dianthus (Goldfuss); Ma, 1937, pl. iv. (Middle Devonian).

Also, *Columnaria sulcata* Goldfuss, Lang and Smith, 1935*a*, pl. xii, figs. 1, 2, seems to me a possible Disphyllid (see p. 241).

GIVETIAN OR FRASNIAN OF WESTERN AUSTRALIA.

Prismatophyllum brevilamellatum Hill, 1936*b*, p. 32, figs. 6–8.

FRASNIAN OF EUROPE.

Cyathophyllum davidsoni Edwards and Haime, 1851, topotype, U. of Qld.

Cyathophyllum boloniense Edwards and Haime, 1851, topotype, U. of Qld.

Prismatophyllum quadrigeminum (Goldfuss); Ma, 1937, pl. iii, fig. 1.

Phillipsastraea pentagona (Goldfuss); Frech, pl. iii, fig. 7.

Phillipsastraea pentagona var. *micrommata* (Roemer); Frech, 1885, pl. iii, figs. 11–13.

Phillipsastraea ananas (Goldfuss); Frech, 1885, pl. iii, fig. 14.

Haplothecia filata Frech, 1885, pl. iv, fig. 7.

Heliophyllum troscheli (Edwards and Haime); Schlüter, 1881, pl. iv, figs. 3, 4.

Heliophyllum cf. *limitatum* (Edwards and Haime); Schlüter, 1881, pl. iv, figs. 1, 2.

FRASNIAN OF AMERICA.

Specimens referred to five species of *Acervularia* Schweigger by Fenton and Fenton, 1924, p. 55, probably are *Prismatophyllum*, but only externals are figured.

The Types of Septa observed in *Prismatophyllum* are:—

1. In the list given above, the French Lower Devonian *namnetensis* and *venetensis*, the European Middle Devonian *hexagonum*, Frech, and Frasnian *pentagonum* and *micrommatum*, *troscheli* and *limitatum* show spindle septa well developed. In spindle septa, dilatation is great towards the inner edge of the dissepimentarium, but lessens towards both axis and periphery. Septa which are not thus dilated may occur in the same corallum.

2. In the American Couvinian and the German Frasnian, the septa have trabecular carinae, opposite or alternate on either side of the septa. The carinae are developed on thick, thin, or spindle septa.

3. In the American Eifelian, the German Givetian, and the French Frasnian, attenuate septa are common; they may be slightly spindled.

4. In the Australian *stevensi* (*vide* infra), the septa are dilated at the periphery and in the dissepimentarium, but attenuate rapidly towards the axis. This is the *Disphyllum depressum* type (see p. 226).

Species with septa not extending beyond the dissepimentarium and species with septa reaching to the axis occur in Lower, Middle and Upper Devonian.

The Tabularium of *Prismatophyllum.*

1. Clisioid; in the American Middle Devonian *sedgwicki* Ma, the tabular floor is domed, and the tabulae are replaced by tabellae; in the German Frasnian *ananas* the tabellae are distinctly grouped in two series, the inner forming a steep dome.

2. In the German Middle Devonian *quadrigeminum* Goldfuss, the French Frasnian *quadrigeminum* Ma, and in the German Frasnian *troscheli* Schlüter, the *Disphyllum minus* type of tabularium occurs with the *goldfussi* type (see p. 225).

3. In the French Lower Devonian *namnetensis,* the American Couvinian *whitfieldi* and the German Frasnian *pentagonum* (Frech) and var. *micrommata* (Frech), and *filatum,* the *Disphyllum geinitzi* type of tabularium (see p. 225) is interrupted by long septa.

4. In the German Middle Devonian *hexagonum* Frech and *dianthus* Ma and the American Couvinian *anna, prisma* and *truncatum,* the *Disphyllum elongatum* type occurs (see p. 225).

The Dissepimentarium is of two types:—

1. In the German Frasnian *troscheli, ananas* and *micrommatum,* there is a change in the direction of inclination of the dissepiments and septal trabeculae near the inner edge of the dissepimentarium. The dissepiments, which are somewhat less globose than in *Disphyllum,* are horizontally based at this critical area, and are inclined on either side. This condition is common in *Phillipsastraea,* but is not yet known in *Disphyllum.*

2. In all other *Prismatophyllum* listed above the dissepiments are inclined towards the axis, the angle of inclination being slight in peripheral series, but increasing in the inner series.

Prismatophyllum stevensi (Chapman).

(Plate XIII, figs. 6, 7.)

Spongophyllum stevensi Chapman, 1925, p. 113, pl. xiv., figs. 17*a, b;* pl. xv, figs. 24, 27; Mitchell's Quarry, Cave Hill, Lilydale.

Spongophyllum stevensi; Jones, 1932, p. 52.

Holotype.—13305, National Museum, Melbourne, L. E. Stevens Collection. A portion of the holotype (the only specimen known) is in the collection of the Geological Department of the University of Melbourne, No. 797. Slides cut from this portion are here figured.

Diagnosis.—*Prismatophyllum* with septa dilated in the dissepimentarium and attenuate in the tabularium, with dissepiments globose distally, and two series of dissepiments forming a concave tabular floor.

Description.—The corallum is cerioid and large, with a diameter of 18.7 cm., and a height of 6.8 cm. The corallites are polygonal, usually pentagonal, subequal and straight, with an average diameter of 6 mm. The septa are usually so dilated in the dissepimentarium as to be in contact laterally, but spaces may be left wherein dissepiments are developed. Usually there are 16 major septa alternating with 16 minor septa. The minor septa extend to the inner edge of the dissepimentarium, that is, one-quarter to one-third of the way to the axis. The major septa are unequal in length. Some few of them extend to the axis, but others are very little longer than the minor septa. Those portions of both orders of septa projecting into the tabularium thin rapidly towards the axis. Neither order of septa are waved or carinate, nor do they twist at the axis. The tabulae are typically of two series, an axial series of flat or sagging plates, and an outer series of smaller, inclined plates. Occasionally, however, only one series is present, one or two flat tabulae extending completely across the tabularium. There are one, two, or three vertical series of dissepiments, small, fine, globose distally, and inclined towards the axis.

Remarks.—In its internal structure this cerioid species resembles very closely the phaceloid *Disphyllum depressum* (Hinde; Hill, 1936, pl. i, figs. 4-8) from the Givetian or Frasnian of Western Australia. It cannot be closely compared with any other *Prismatophyllum* and so does not indicate any particular period, but the known range of the genus is Devonian and possibly Lower Carboniferous. Its septa are like the septa of *D. depressum*. Its dissepiments are those characteristic of the genus, the outer peripheral series being larger and more horizontally based than the others, as in *D. goldfussi*. Its tabularium is divided into an inner and an outer series, like that of *D. panicum*.

The species can thus be removed to the Family Disphyllidae, as it possesses all the salient features of that group, as these were described recently by Lang and Smith (1935*b*). It resembles *Spongophyllum*, however, in having concave tabulae, but in the Spongophyllidae the concave tabulae are parallel and close together, whereas in *stevensi* the tabularium has the lack of parallelism characteristic of the *D. panicum* type (see p. 225).

Prismatophyllum chalkii (Chapman).

(Plate XIII, figs. 1–5.)

Acervularia chalkii Chapman. 1931, p. 94, text-fig. Cave Hill, Lilydale, Victoria. Lower or Middle Devonian.

Holotype.—Specimen in Mr. Chapman's Collection, Melbourne.

Diagnosis.—*Prismatophyllum* with slightly carinate septa dilated towards the inner edge of the dissepimentarium; the major septa are withdrawn from the axis; the calical floor rises from the periphery to the inner edge of the dissepimentarium; the tabulae are distant, and complete, and slightly domed or saucered plates are mixed indiscriminately with incomplete plates inclined towards the axis.

Description.—The corallum is cerioid, increase being intermural, the offsets often arising in a ring round the parent, both at the angles and along the sides. The divisional walls between the calices are rather thin in the holotype, with a tendency to zig-zag, as in semi-astracoid coralla, but are of fair thickness in some fragments (F 3254–5, University of Queensland Collection; 1654–5 in Melbourne University Geology Dept. Colln.). No external view of the species has been obtained. The corallites vary very much in size, 8 mm. being the greatest diameter observed; the offsets are 1 mm. in diameter at origin, and at this size the septa are all extremely short, forming a mere fringe, rather ragged, round the offset, which consists therefore mostly of tabularium; no dissepiments are observed in the offsets when they first arise, but they appear as the diameter increases; at first the septa are equally dilated from epitheca to tabularium, but at greater diameters the peripheral parts are thinner. In the adult coralite (6–8 mm. in diameter) there are 26–30 septa, usually 28. They are all spindle shaped in transverse section, because of their attenuation towards the periphery and again towards the axis; their thickest part is just outside the inner edge of the dissepimentarium; they are usually carinate and therefore are wavy in transverse section, the carinae being directed at right angles to the inclination of the dissepiments like the trabeculae, which have an area of divergence near the inner edge of the dissepimentarium; to the outside of this the trabeculae are inclined upwards and outwards, and to the inside they are inclined upwards and inwards. This condition is well seen in Frech's figure (1885, pl. iii, fig. 14) of *Phillipsastraea ananas* Goldfuss. In some parts of the holotype, however, the septa are thin; the minor septa are usually a little thinner than the major septa. The major septa may proceed into the tabularium, sometimes almost to the axis, as very thin wavy extensions, but in most corallites they are only as long as the minor septa. The dissepiments are very fine, globose plates; most of them are inclined towards the periphery, but near the inner edge of the dissepimentarium they are horizontally based, giving a series like horse-shoe dissepiments but not so globose, and inside this they are inclined towards the axis. In transverse section those plates inclined towards the periphery have their concavity outwards, and frequently they are geniculate; a herring-bone pattern may be produced by the inosculation of two series of dissepiments in each interseptal loculus, one dependent on each of

the bounding septa. The innermost series of dissepiments may be dilated; but whether this dilatation is composed of trabecular extensions from the septa as in *Phacellophyllum* or by a thickening of the horizontal tissue cannot be determined from the material I have. The tabulae are distant and irregular; some are complete, horizontal or slighty saucered; others are incomplete and are inclined towards the axis.

REMARKS.—This species has the structure of those Devonian species placed in *Acervularia* Schweigger by Edwards and Haime (1851); the differences between the Silurian and Devonian species of Edwards and Haime's interpretation were first recognized by Simpson (1900, p. 218) who founded *Prismatophyllum* for the Devonian species, but were not generally accepted until Lang and Smith's work on both genotypes was published (1927, p. 451; 1935*b*, p. 558).

This is the only known species of *Prismatophyllum* in which short major septa are combined with an area of divergence in the inclination of the dissepiments and trabeculae. Other species with major septa which do not extend into the tabularium are the Lower Devonian *venetensis,* the American Couvinian *anna, truncatum,* and *kirki,* the Givetian or Frasnian *brevilamellatum,* and the Frasnian *limitatum* E. & H., Schlüter (1881, pl. iv, figs. 1, 2). Other species with an area of divergence of dissepiments and trabeculae are "*Philipsastraea ananas* G." Frech (1885, pl. iii, fig. 14), and *Prismatophyllum approximans* (Chapman, 1914, pl. xlvii) from Victoria.

It is not possible to compare *P. chalkii* closely with any other species of *Prismatophyllum,* and therefore the only assistance it gives in indicating the age of the Lilydale limestone is that the genus is known elsewhere only in the Devonian.

Genus TRAPEZOPHYLLUM Etheridge.

Trapezophyllum Etheridge, 1899, p. 32.

GENOTYPE (by designation): *Cyathophyllum elegantulum* Dun, 1898, p. 85, pl. iii, figs. 5, 6. Limestone Quarry, Loyola.

DIAGNOSIS.—Cerioid Rugose corals with an outer series of flat dissepiments, an inner series of horse-shoe dissepiments, and complete, concave tabulae.

REMARKS.—A frequent development in the phaceloid members of the Disphyllidae is the arrangement of the dissepiments into an outer single series of flat plates, and an inner single series of horse-shoe dissepiments. The cerioid members are so far without such a representative in Europe or America, and it is therefore of interest that the Victorian species *Cyathophyllum elegantulum* is such a cerioid form. The phaceloid species showing these characteristic dissepiments are grouped by Lang and Smith into a genomorph of *Disphyllum* {*Phacellophyllum*} Gürich. It may be that the Australian *C. elegantulum* should be regarded as a

genomorph of the cerioid *Prismatophyllum*; but until more evidence of its phylogeny is obtained it is best referred to the genus *Trapezophyllum*. Etheridge made the species the type of a new section of the genus *Cyathophyllum* characterized by the equality and shortness of the septa. But the work of Lang and Smith indicates that its relations are with the *Disphyllum* group; hence the character of the dissepiments is more important diagnostically than the length of the septa. The genus is known only from Loyola, although Etheridge suggested that *C. pelagicum* Billings (1862, p. 108) and *C. wahlenbergii* Billings (*id.*) from the Silurian of Canada should be placed under *Trapezophyllum*. *C. wahlenbergii* seems from the figures (Lambe, 1901, pl. xi. fig. 2) to be *Xylodes rugosus*. *C. pelagicum* is unfigured.

Trapezophyllum elegantulum (Dun).

(Plate XVI, figs. 9–11.)

Cyathophyllum elegantulum Dun, 1898, p. 85, pl. iii, figs. 5, 6.

Cyathophyllum ? elegantulum; Etheridge, 1899, p. 31, pl. B, figs. 2–4. Sections figured 3, 4, are A.M.2 in Australian Museum.

C. (*Trapezophyllum*) *elegantulum*; Etheridge, 1899, p. 32.

Holotype.—41717, Collection of the Geological Survey of Victoria, formerly part of 107, George Sweet Collection. Limestone Quarry, Loyola. Figured Dun *loc. cit.*, Etheridge *loc. cit.*

Diagnosis.—*Trapezophyllum* with major and minor septa equal and extending half-way to the axis.

Description.—The corallum is cerioid, of unknown shape. Increase is intermural, but sometimes the offsets are not separated from the parent corallites by epitheca, and the corallum is thus locally thamnastraeoid. The corallites are usually hexagonal, with a diameter between 2 and 4 mm. There are 10 to 12 major septa alternating with minor septa, but the minor septa are only with difficulty distinguished from the major septa, both series extending half-way to the axis. They are thin and do not show carinae, but their axial ends are dilated and rarely in contact. Occasionally very short tertiary septa are seen. The dissepiments are arranged in two series; an inner single series of small horse-shoe dissepiments is regularly developed between the axial ends of the septa, and the outer development is usually of a single series of plates transverse or slightly inclined to the periphery, rather fewer than the horse-shoe dissepiments, but there may be two columns of plates which in vertical section are flattened on top and bulge towards the axis, a number giving the appearance of superposed rhombs. The tabulae are complete, and flat or sagging, about 5 in the space of 5 mm.

Remarks.—The sporadic occurrence of tertiary septa is unusual. No comparable cerioid species is known. The phaceloid *Disphyllum* {*Phacellophyllum*} has a similar dissepimentarium,

but the tabularium and septa of *Trapezophyllum elegantulum* are distinctive. *Phacellophyllum* occurs in the European Lower Devonian, Givetian and Frasnian.

Genus PHILLIPSASTRAEA d'Orbigny.

Phillipsastraea d'Orbigny, 1849, p. 12.

Phillipsastraea; Lang and Smith, 1935*b*, p. 556, q.v. for synonymy.

GENOTYPE.—*Astraea Hennahii* Lonsdale, 1840, p. 697, pl. lviii, figs. 3, 3*b* (see Lang and Smith *loc. cit.*). Upper Devonian, Barton Quarry, Newton, Plymouth.

DIAGNOSIS.—Plocoid Rugose corals; typically the septa are dilated at the margin of the tabularium, and are usually carinate; there is no columella, and the tabulae are horizontal, complete or incomplete; dissepiments are numerous, small and rather globose, and those at the inner edge of the dissepimentarium may be horse-shoe shaped.

REMARKS.—Plocoid corals occur commonly in the Devonian, and those which show the characters of the Disphyllidae—globose dissepiments frequently divided into more than one series, septa which are carinate with trabecular carinae, spindled, or dilated in the dissepimentarium, and tabulae typically of two series—may be placed in the genus *Phillipsastraea*, in conformity with Lang and Smith's division of the Disphyllidae into genera primarily according to the form of the corallum.

The oldest species which has been placed in *Phillipsastraea* is *walli* Etheridge (1892, p. 169, pl. xi, fig. 7) from the Lower Ludlow of New South Wales. This is plocoid, but its dissepiments are not so globose as in typical Disphyllidae, nor are its tabulae, which are deeply concave, differentiated into two series, and its septa show none of the modifications of the Disphyllidae. It may be that this species is not a member of the Disphyllidae at all, and should therefore be moved from *Phillipsastraea*. It differs from *Arachnophyllum*, the Silurian plocoid genus, in having neither the septal modification nor the axial structure of that genus, and in having parallel, deeply concave, complete tabulae. No figures of the fine structure of *P. silurica* Lahusen are available, but Weissermel (1894, p. 611) considered it a true Silurian *Phillipsastraea*.

No figures of the fine structure of the Bohemian Lower Devonian *P. cuncta* Počta (1902, pl. 113, fig. 18) are available, and the plocoid form from the Lower(?) Devonian of Ellesmereland referred to *P. gigas* Billings by Loewe (1914, p. 14, pl. iv, fig. 2) is insufficiently figured.

Stumm (1937) has considered the Eifelian plocoid species of Nevada to be separable from *Phillipsastraea*, and has placed them in *Radiastraea* Stumm (1937, p. 439) and *Billingsastraea* Grabau. Leowe (1914) considered three species from the Middle Devonian

of Arctic America to be *Phillipsastraea*, but his figures are insufficient. No *Phillipsastraea* has been recorded as such from the Middle Devonian of Europe, but *Keriophyllum astraciforme* Sochkina (1936, p. 63, figs. 71-72) from the Northern Urals may be one.

From the Upper Devonian comes the type *P. hennahii*, a form with spindle septa, a dissepimentarium in which there is an area of divergence in the inclination of the plates near the inner boundary, and a tabularium of the *Disphyllum goldfussi* type (see p. 225). *P. boloniense* (see Lang and Smith 1935*b*, p. 556, text-figs. 12-13) has similar septa, but the dissepiments are horizontally based near the periphery, and steeply inclined at the inner edge of the dissepimentarium. The tabulae are of the *Thamnophyllum* type. *P. delicatula* Hill (1936, p. 30, text-figs. 4, 5) from Western Australia has unthickened septa, but dissepiments and tabulae as in *boloniense*. The Upper Devonian of Europe and America has a second group of Phillipsastraeids commonly but wrongly called *Pachyphyllum* (see Lang and Smith, 1935*b*, p. 555), such as *devoniense* (Edwards and Haime, 1852, p. 397), *bouchardi* (Edwards and Haime, 1851, pl. 7, fig. 7), *ibergense* (Roemer, 1855, pl. vi (xxi), fig. 24), *johanni* (Hall and Whitfield; Fenton and Fenton, 1924, pl. xv, figs. 6, 7), *woodmani* (White; Fenton and Fenton, 1924, pl. vii, figs. 1-3) etc. This second group is known so far only from the Upper Devonian, and is characterized by the excessive dilatation of the septa near the inner margin of the dissepimentarium.

The only record of a *Phillipsastraea* from Asia is that of "*Smithia hennahi*" in Deprat and Mansuy, 1912 (*fide* Yabe and Hayasaka 1920, p. 101) from the Couvinian of Yun-nan.

Range.—Upper Devonian of Europe, America and Western Australia. Doubtfully from the Upper Silurian of New South Wales and the Baltic states, from the Lower Devonian of Bohemia, and from the Middle Devonian of Europe and Arctic America.

Phillipsastraea speciosa Chapman.

(Plate XVI, figs. 1–4.)

Phillipsastraea speciosa Chapman, 1914, p. 306, pl. xlix, figs. 10, 11; Plate I, figs. 12–14. Griffith's Quarry, Loyola, near Mansfield.

Holotype.—2487, W. H. Ferguson Collection, Geological Survey of Victoria, and two slides cut from it, here figured, 1387 and 1388, National Museum, Melbourne.

Diagnosis.—Astraeoid *Philipsastraea* with spindle septa sometimes extending to the axis as thin plates or as discontinuous trabeculae, or projecting just within the tabularium; with the

greatest height of the floor of the dissepimentarium at its inner border, the outer dissepiments being inclined towards the periphery; and with concave tabulae.

Description.—The corallum is astraeoid and spreading, the greatest thickness observed being 24 mm. The corallites are 4 to 6 mm. wide, irregularly pentagonal and not bounded by an epitheca, their margins being defined by lines along which the septa are turned aside to meet those of neighbouring corallites at an angle. The tabularia are about 2 mm. in diameter, and from 4 to 7 mm. apart. The stereozone is narrow, at the inner edge of the dissepimentarium. There are from 26 to 30 septa, alternately major and minor. They are dilated so as to be in contact or almost so at the inner edge of the dissepimentarium, but the dilatation decreases very gradually outwards. They never become attenuate, and in some cases may be carinate. The carinae are extensions from the trabeculae, and may be opposite or sub-opposite, when the septum appears zig-zag in transverse section. The trabeculae are more or less distinct, and have an area of divergence near the inner border of the dissepimentarium. The minor septa end rather bluntly just inside the tabularium, but the major septa sometimes extend to the axis, thinning very gradually as they do so, or being represented by discontinuous trabeculae; or they may be very little longer than the minor septa. The tabulae are shallowy concave, usually complete, and they may be supplemented at the margin of the tabularium by small inclined tabellae. In some corallites when the septa are very long, the tabulae are domed. The dissepiments are globose and very small, and frequently do not extend completely across the interseptal loculi, but inosculate with one another. The innermost series is more globose and projects higher than the rest of the tissue; they are almost horse-shoe dissepiments. The others are disposed horizontally or inclined towards the periphery.

Remarks.—The species is close to the species-group of the genotype from the Upper Devonian of Europe. In the manner of its septal dilatation, and the size of the corallites, it is closest to the form figured by Edwards and Haime (1853, pl. 54, fig. 4) but the variation in the development of the septa within the dissepimentarium distinguishes it; the discontinuous trabeculae are not seen in *hennahii,* to my knowledge.

Corallites in which the major septa are short closely resemble those of *P. currani* Etheridge (1892, pl. xi, figs. 1–6) from Fernbrook, New South Wales, except that they are smaller.

Phillipsastraea sp. indet.

(Plate XVI, figs. 5, 6.)

Phillipsastraea walli Etheridge; Chapman, 1914, p. 305, pl. xlviii, figs. 7–9, Loyola; *non Phillipsastraea walli* Etheridge, 1892, p. 169, pl. xi, fig. 7, Upper Silurian, Yass, New South Wales.

Material.—Two slides, 1374 and 1375 (figured *mihi*, and Chapman *loc. cit.*), National Museum, Melbourne, cut from specimen 2491, whose whereabouts are unknown; and three slides cut from specimen 2489, W. H. Ferguson Collection, Geological Survey Museum, Melbourne, Victoria. All from Griffith's Quarry, Loyola, near Mansfield.

Description.—The corallum is thamnastraeoid or in part astraeoid; the tabularia are 1.5 to 2 mm. in diameter, and 3 to 6 mm. apart. There are 22 to 24 septa, half of which extend further towards the axis than the others (the minor septa), which project only very slightly into the tabularium. The septa are all thin, with short, sharp irregular waves, and are continuous throughout the dissepimentarium, not being broken up by the dissepiments. The dissepiments are small, crowded, and frequently geniculate. Their reverse curvature in the peripheral parts of the dissepimentarium suggests that there is an area of divergence in their inclination, as in *speciosa*. An inconclusive vertical section shows distant, horizontal, complete tabu'ae.

Remarks.—The New South Wales Upper Silurian *walli* Etheridge is distinguished by the discontinuity of the septa in the outer parts of the dissepimentarium, by the marked radiality of arrangement of the septa in a wreath round the tabularium, and by the deep almost parallel-sided concavity of the tabulae; Loyola specimens show none of these three characters, and I think that the equation of the Loyola specimens to *walli* cannot be sustained, in spite of the general similarity in size of corallite and number of septa. On the other hand the specimens show some similarity to *speciosa*, with which they occur, but not the spindle septa believed to be characteristic of *speciosa*. More material is necessary for a safe determination of the species.

Genus LOYOLOPHYLLUM Chapman.

Loyolophyllum Chapman, 1914, p. 306; proposed as sub-genus of *Columnaria* Goldfuss, 1826 (= *Favistella* Hall, 1847); by a typographical error the name is spelt *Loyolophyllia* on p. 301.

Genotype, by monotypy: *Columnaria* (*Loyolophyllum*) *cresswelli* Chapman, 1914, p. 306, pl. li, figs. 15, 16; pl. lii, figs. 17, 18. Griffith's Quarry, Loyola, near Mansfield.

Diagnosis.—Cerioid corals with small corallites, thin septa, complete, horizontal or saucered tabulae, and sporadically an incomplete series of vertically elongate dissepiments lining the wall in the interseptal loculi.

Range.—The genus is known only from the type locality.

Remarks.—Chapman observed that this form was very similar in structure to *Columnaria* of the *alveolata* morphology, and regarded it as a sub-genus of *Columnaria*, from which it differed by the tabulae being saucered rather than domed, and by the

presence of dissepiments. Like Etheridge (1918, p. 53), I consider these distinctions, particularly the presence of dissepiments, to be generic in value, and, like Chapman, I consider the genus to be related to *Columnaria alveolata,* i.e. to *Favistella* Hall. There is, however, some doubt whether the family should be called Columnariidae or Favistellidae, and for this reason I have departed from the orthodox method of reviewing the family before the genus. The family and the difficulties in its nomenclature are discussed in the following remarks on *Favistella* and similar genera:—

There are in the Ordovician, Silurian and Devonian a number of compound corals whose structure is very simple—major and very short minor septa, and tabulae, without mural pores. Goldfuss (1826) founded the genus *Columnaria* for such forms, his syntypes being *alveolata* from the Ordovician of North America (a species later described as *Favistella stellata* by Hall, 1847), *laevis* from the ? Jurassic of Italy, and *sulcata* from the Devonian of Prussia. The first of these has no dissepiments; but the third, which was chosen by M'Coy (1849, p. 121) as the genolectotype, has. Most authors have, however, followed Edwards and Haime's later (1851, p. 308) and therefore invalid selection of *C. alveolata* as type, and have interpreted *Columnaria* as synonymous with *Favistella* Hall.

Frech (1891, *fide* Weissermel, 1897, p. 867) considered the genus *Cyathophylloides* Dybowski (1873, p. 379), with genosyntypes *kassariensis* Dybowski, *fasciculus* Kutorga and *irregularis* Dybowski, as a synonym of *Columnaria;* and indeed Weissermel's figures (1897, p. 871) of *kassariensis,* which Lang and Smith (1935*b*, p. 543) chose as genotype of *Cyathophylloides,* show a generic similarity to *Columnaria alveolata,* and *Cyathophylloides* is to be regarded as synonymous with whatever genus takes *alveolata.*

Weissermel (1897) recognized four compound species and two solitary species, all with thick walls and without dissepiments, as a sub-genus of *Columnaria* (which he appears to have interpreted on *alveolata*). These species were: the phaceloid *Densiphyllum tamnodes* Dybowski from the Ordovician of Estland, the cerioid *Cyathophylloides* (*Densiphyllum*) *contorta* Weissermel (1894, pl. 1, fig. 2) from the Ordovician or Silurian of Europe, the cerioid *Columnaria devonica* Schlüter (1889, p. 272) and the phaceloid *Columnaria rhenana* Frech (1886, pl. iii, fig. 19) from the Devonian of Germany, and the solitary *Densiphyllum thomsoni* Dybowski and *Densiphyllum rhizobolon* Dybowski, both from the Ordovician of Estland. Weissermel named the genus *Pycnophyllum* Dybowski, *Pycnophyllum* being a correction for *Densiphyllum* Dybowski, made (*fide* Weissermel, 1897, p. 867, footnote) by its author. But by Article 19 of the Rules of Zoological Nomenclature, the original orthography of

a name is to be preserved unless an error of transcription, a *lapsus calami,* or a typographical error is evident, so that *Densiphyllum* must be retained for Dybowski's genus. No type has ever been chosen for *Densiphyllum,* and until good sections of Dybowski's syntypes have been illustrated, critical remarks on the extent and relations of the genus are without value.

Lang and Smith (1935*a*) studied Goldfuss' specimens of *alveolata* and *sulcata,* and concluded that they were congeneric. But this conclusion I doubt, from the evidence of the published figures. The vertical sections which they figure from the type of *sulcata* show dissepiments, very similar to, but perhaps less globose than, those of *Disphyllum geinitzi* figured by the same authors (compare L. and S. 1935*b*, pl. xxxvi, fig. 3, with L. and S., 1935*a,* pl. xii, fig. 2, which is inverted). And it seems to me that *sulcata* might easily be a cerioid member of the Disphyllidae, with the internal structure closely similar to that of *D. geinitzi.*

Should a re-study of the type material confirm my opinion, then *Columnaria* would have to be applied only to such cerioid Disphyllidae, and not to species like the Ordovician *alveolata,* which have no dissepiments. For the latter, Hall's name *Favistella* would need to be revived, and *Cyathophylloides* Dybowski regarded as synonymous with it, and not with *Columnaria.*

Lang and Smith (1935*b*, p. 548) have considered *Fasciphyllum* Schlüter (1885, p. 52, genotype, by designation, "*Fascicularia?*" *conglomerata* Schlüter, 1880, p. 147 from the Givetian of the Eifel) to be a synonym of *Columnaria* (genotype *sulcata*). *Conglomeratum,* however, possesses a single series of vertically elongate dissepiments like those found in *Loyolophyllum;* i.e., they are dependent on the wall in the interseptal loculi, and are unlike those of *sulcata.* No dissepiments occur in *alveolata,* and I cannot accept that *conglomeratum* is congeneric with either *sulcata* or *alveolata,* but consider that palaeontological comparisons will probably be more exact and stratigraphical correlation made easier by regarding these three species as belonging to different genera, thus: *Columnaria sulcata, Favistella alveolata,* and *Fasciphyllum conglomeratum.*

In summary, a study of the published figures leads me to the view that the species we have been considering are best grouped as follows:—

Family DISPHYLLIDAE.—The Middle Devonian cerioid *Columnaria sulcata* Goldfuss, *Columnaria arctica* (Loewe, 1914, pl. ii, fig. 3, Ellesmereland).

Family FAVISTELLIDAE.—*Favistella alveolata* (Goldfuss = *F. stellata* Hall), cerioid, from the American Ordovician; *Favistella calicina* (Nicholson, 1874; 1879, pl. x, fig. 2), phacelocerioid, American Ordovician; *Favistella fascicula* (Kutorga,

Weissermel), phaceloid, Ordovician of the Baltic States; *Favistella kassariensis* (Dybowski, Weissermel), cerioid, Silurian of the Baltic States; *Favistella gothlandica* (Edwards and Haime, 1851, pl. 14, fig. 2), cerioid, Silurian of Gotland; *Favistella pauciseptata* (Etheridge, 1897, pl. viii), cerioid, Silurian of New South Wales; *Favistella neminghensis* (Etheridge, 1918, pl. ix), cerioid, Devonian of New South Wales; *Favistella symbiotica* (Charlesworth, 1914, pl. xxxi, fig. 2), phaceloid, Lower Devonian, Eastern Alps; *Fasciphyllum conglomeratum* (Schlüter, phaceloid, Middle Devonian of Germany), ?, = *Cyathophyllum syringoporoides* Charlesworth (1914, pl. xxxi, fig. 1, Lower Devonian, Eastern Alps); *Loyolophyllum cresswelli* Chapman, cerioid, Lower Devonian, Victoria.

In all probability some of the species placed by Weissermel in the sub-genus *Densiphyllum* (see p. 240), are members of the Favistellidae.

Thus in the author's opinion *Loyolophyllum* is a member of the Favistellidae. Its closest relative is *Fasciphyllum* Schlüter from the Lower Devonian of the Eastern Alps and the Middle Devonian of Germany. It is cerioid, whereas *Fasciphyllum* is phaceloid. These dissepimented Favistellids differ from *Spongophyllum kunthi* Schlüter (1880; 1881, pl. viii, figs. 1, 2, Couvinian, Germany) and related forms in that the dissepiments do not break through the septa but occupy the loculi between them, whereas in *kunthi* the dissepiments are lonsdaleoid, and the septa are withdrawn from the periphery.

Loyolophyllum cresswelli Chapman.

(Plate XV, figs. 8–11.)

Columnaria (Loyolophyllum) cresswelli Chapman, 1914, pp. 306–8, pl. li, figs. 15–16; pl. lii, figs. 17–18. Griffith's Quarry, Loyola.

Loyolophyllum cresswelli; Etheridge, 1918, p. 51.

Holotype.—12904, and 5 paratypes (12905–9). A. W. Cresswell's Collection, National Museum, Melbourne.

Diagnosis.—As for genus.

Description.—The corallum is cerioid, mushroom shaped, expanding very rapidly from an apex, attaining a diameter of 10 cm. Increase is intermural. The corallites are usually hexagonal, with average diameter 2 mm., though they are only 1.13 mm. in the type. There are 10 septa, continuous at their bases with a very narrow peripheral stereozone, about 0.25 mm. thick. The major septa are unequal in length; four to six may extend almost to the axis, as in *Stauria*. The minor septa may be one-third as long as the major septa. The septa show no carinae; some sections suggest that they are acanthine, but the material is very badly preserved. Development of the elongated dissepiments is variable; it may be limited to a few scattered

plates adhering to the epitheca by their upper and lower edges; or the lower edge of one plate may rest on the upper part of an earlier dissepiment; or one complete vertical series may be formed. The tabulae are complete, usually sagging, sometimes horizontal, about 10 in the space of 1 cm.

REMARKS.—This cerioid species has a similar internal structure to the phaceloid *Fasciphyllum conglomeratum* (Schlüter) from the Middle Devonian of Germany and *Fasciphyllum syringoporoides* (Charlesworth) from the Lower Devonian of the Eastern Alps, as already mentioned in the remarks on the genus.

ZOANTHARIA RUGOSA INCERTAE SEDIS.

Genus LYRIELASMA nov.

(Lurion = a lyre, elasma = a plate; from the fanciful resemblance of the septa to the strings of a lyre.)

GENOTYPE.—*Cyathophyllum subcaespitosum* Chapman, 1925, p. 112, pl. xiii., figs. 15, 16*a*, *b*. Cave Hill, Lilydale.

DIAGNOSIS.—Fasciculate Rugosa with the major septa directed towards the median plane, with wide, deeply concave incomplete tabulae, and with a peripheral stereozone of irregular width, formed by the dilatation of major and minor septa in the dissepimentarium.

RANGE.—The genus is known with certainty only from the Lower Devonian of Loyola, and the Lower of Middle Devonian of Lilydale, Victoria. Possible species, however, occur in the Lower and Middle Devonian of Europe.

RELATIONS.—*Lyrielasma* shares the arrangement of its septa and the deep concavity of its tabulae with the European Silurian *Cymatelasma* Hill and Butler (1936) and *Spongophylloides* Meyer (see Butler, 1934), and with a large number of German and American Devonian forms. It differs from *Cymatelasma* and *Spongophylloides* in being compound and in the characters of the dissepimentarium. No dissepiments at all have been seen in the peripheral stereozone of *Cymatelasma;* in *Spongophylloides* there is a lonsdaleoid border of very steeply inclined dissepiments. In *Lyrielasma* dissepiments occur fairly frequently within the interseptal loculi in the peripheral stereozone, but usually do not cause the septa to become discontinuous; they are steeply inclined like those of *Spongophylloides.* It does not seem reasonable to place *Lyrielasma* with the Cymatelasmidae. The classification of the Devonian forms into genera and families is not yet satisfactory. Wedekind (1924, 1925) in his study of the Rugosa of the German Couvinian and Givetian, has placed such Givetian corals into the family Stringophyllidae, most of them showing in addition a tendency for the septa to be represented in the dissepimentarium by discontinuous trabeculae. *Lyrielasma* differs

from this group in having the septa continuous and dilated in the dissepimentarium. The Couvinian Digonophyllinae deseribed by Vollbreeht (1926) differ ehiefly in the presenee of a key-hole fossula in the tabularium.

It is possible that this arrangement of septa and tabulae is a homeomorphic development which is as much eharaeteristie of the Devonian as the axial strueture is characteristic of the Carboniferous.

The arrangement and peripheral dilatation of the septa of some forms from the Upper Ludlow of the Urals, placed by Sochkina (1937, pl. xiv, figs. 1-5) in *Omphyma*, recall *Lyrielasma*, but the Russian species have large lonsdaleoid dissepiments and tabulae which are flat rather than concave, and I do not think any elose relation is indicated.

Species from the Lower Devonian of the Eastern Alps and the Chalonnes Limestone, and from the Middle Devonian of the Eifel, which might belong to the genus, are diseussed in the remarks on the genotype.

Lyrielasma subcaespitosum (Chapman).

(Plate XIV., figs. 1–6, plate XV, figs. 6, 7.)

Cyathophyllum subcaespitosum Chapman, 1925, p. 112, pl. xiii, figs. 15, 16*a*, *b*. Cave Hill, Lilydale.

Holotype.—1731 and 14065, National Museum, Melbourne.

Diagnosis.—*Lyrielasma* with wide, low, septal carinae, parallel to the distal edges of the septa.

Description.—The corallum is fasciculate, the eorallites diverging slightly. The largest fragment of corallum is 75 mm. in diameter and 60 mm. high; the corallites in it are unequally spaced, being in contact or very close immediately after increase, and up to 10 mm. apart later; they have an average diameter of 12 mm., and may be slightly compressed. The epitheca shows faint longitudinal grooves, with broad ribs. Growth annulation is also faintly marked. No ealices are available for study.

There are from 24-30 major septa, alternating with an equal number of minor septa, the number increasing as the width of the corallum grows from 8 mm. to 12 mm. The minor septa may be two-thirds as long as the major septa. The septa are dilated and in contact in a peripheral stereozone of variable width; in many corallites it is mostly as wide as the dissepimentarium, and in these the septa are moderately dilated in the tabularium also; but in a few (one in the holotype, and two individuals found isolated—F 1329*a*, *b*, Australian Musenm) it is very narrow, and the septa are almost attenuate. The septa are slightly waved, the crests of the waves running along the sides of the septum, parallel to its upper edge; sometimes, particularly when the septa are thin, the crests are angular, and

thin carinae grow out from them. The septa are directed towards a median plane of the tabularium; this plane is probably that of the cardinal and counter septa, but direct proof is lacking. The septum at each end of the plane is usually very short, particularly in the larger corallites; but occasionally, in the smaller corallites, one may be very long, extending to the axis; this long one is presumably the counter-septum. The two or three neighbours of these "directive" septa are usually curved slightly towards the axial ends of the "directive" septa. The remaining septa are not curved, and are unequal. Dissepiments are developed when the dilatation of the septa is not so great as to fill the interseptal loculi; they are equal and steeply inclined as in *Spongophylloides.* Discontinuity of the septa occurs extremely rarely—in one individual in the holotype, the section showed a few scattered lonsdaleoid dissepiments (plate xiv, fig. 1). The tabularium is usually oval, and is just more than one-third the width of the corallite in the direction of the median plane, and just less than one-third this width in the direction at right angles. The tabular floors are inverted cones; the tabellae are wide and shallowly curved, and slope at about 60° towards the axis, about three in the space of 2 mm. The dissepiments, when they are free to develop in the interseptal loculi because the septa are not dilated, are smaller, and more globose, and less steeply inclined than the tabellae.

Occurrence.—Three corallites probably from one corallum have been collected from Griffith's Quarry, Loyola, in the Lower Devonian. They show somewhat greater dilatation than the types from Lilydale, and in all three the counter-septum is very long.

Remarks.—A corallite figured by Charlesworth (1914, pl. xxxi, fig. 8, *non* fig. 7) from the Lower Devonian Reef-limestone of the Eastern Alps is so similar in transverse section to *L. subcaespitosum* that it might have been drawn from the type, but a longitudinal section is needed before generic identity can be proved. Le Maitre has described and figured very similar individuals from the Chalonnes limestone, France, as *Cyathophyllum elongatum* Le Maitre (1934, p. 152, pl. v, figs. 10-12) and *Cyathophyllum dianthus* Goldfuss. She considers the Chalonnes limestone to occupy a horizon transitional between Coblenzian and Couvinian. Specimens (Sedgwick Museum, Cambridge, A 8636, A 9100, and A 9102-3) from the Middle Devonian of the Eifel differ from the Victorian species in the absence of dilatation, in the greater length of the septal carinae, and in the less conspicuous median plane. But close relationship, probably generic, is indicated by the general arrangement of the plates.

In the oval tabularium and the waving of the septa, the Upper Silurian species placed by Sochkina (1937, p. 74, pl. xiv) in *Omphyma* resembles *L. subcaespitosum,* but the horizontal

skeletal elements are very different. Differences from the Silurian *Cymatelasma* and *Spongophylloides* have been sufficiently noticed in the remarks on the genus.

Genus MICTOPHYLLUM Lang and Smith.

Mictophyllum Lang and Smith, 1939, p. 155.

Genotype.—*Mictophyllum nobile* Lang and Smith, *id.*, pl. iv. Upper Devonian (Frasnian), Lower Chute, Redknife River, a tributary of the Mackenzie R., which enters the main stream between Great Slave Lake and Fort Simpson, North-West Canada. Pl. XIII, figs. 8–9.

Diagnosis.—Simple Rugose corals with septa at first dilated in the dissepimentarium and thin in the tabularium, later thinning in the dissepimentarium also; the axial ends of the major septa have an irregular vortical curvature. The tabulae are domed and replaced by tabellae. The dissepiments are geniculate and sometimes dilated, the dilatation being continuous with that of the septa, and are small, rather globose and steeply inclined.

Remarks.—In the irregular vortical curvature of the axial ends of the septa, the geniculate dissepiments, and the domed, incomplete tabulae, this genus resembles the Australian Upper Silurian Phaulactid *Hercophyllum* Jones (1936, p. 53). But in *Hercophyllum* as in other Phaulactids the septa are never dilated in the dissepimentarium, while in *Mictophyllum* a peripheral stereozone is present in the young stages. I have seen figures of only one European species which may belong to this genus. This is *Cyathophyllum graecense* Penecke (1894, p. 600, pl. viii, figs. 14, 15; pl. xi, figs. 5, 6) from the Coblenzian *Heliolites barrandei*-beds of Graz, Austria. Thus the known range of the genus is Lower Devonian of Europe and Upper Devonian of Canada.

I cannot indicate any genus as being closely related to *Mictophyllum*, and so have not placed it in any family.

Mictophyllum cresswelli (Chapman).

(Plate XIV, figs. 7–11.)

Cyathophyllum cresswelli Chapman, 1925, p. 111, pl. xiii, figs. 11–14. Cave Hill, Lilydale.

Holotype.—1267 and 1270 (one corallum cut vertically), National Museum, Melbourne.

Diagnosis.—Sub-cylindrical, erect or slightly curved *Mictophyllum* with long minor septa.

Description.—At first the corallum is patellate and curved (13302, National Museum, Melbourne); later increase in diameter is gradual, and the corallum is sub-cylindrical and erect or but

slightly curved. The largest diameter seen is 34 mm., and the greatest length (fragment only) is 76 mm. There are slight rejuvenescence constrictions in diameter in most corallites. The epitheca shows fine growth annulation, broad, low longitudinal ridges, and narrow longitudinal furrows. The calice is not known.

At 14 mm., the diameter of the smallest cross-section observed, the outer edges of the 32 major septa and 32 minor septa are dilated and in contact in a peripheral stereozone 1.5 mm. wide. The inner part (about 1 mm.) of each minor septum is attenuate, so that the dissepiments, usually curved, sometimes geniculate, develop in the loculi. The axial ends of the major septa are attenuate and extend unequally almost to the axis; the curvature of these ends is irregular and the interseptal loculi are unequal.

At a diameter of 23 mm. (Australian Museum F. 1242), 38 major septa and 38 minor septa are present. The peripheral stereozone is 2 mm. wide, and the length of the unthickened axial parts of the minor septa is 2 mm. The dissepiments between these unthickened parts are thin and usually curved, though sometimes geniculate. The curvature of the axial ends of the major septa is vortical, but irregular due to the different widths of the interseptal loculi.

At the average adult diameter of 28 mm., 35 major septa and 35 minor septa are present, and the fossula is indistinct. The minor septa are slightly thinner than the major septa, and are about two-thirds as long. Dilatation decreases as the height of the corallum increases, and no continuous stereozone is present in the later stages, interseptal loculi separating the septa right to the epitheca; but where there is dilatation, it is continuous from septum to septum across the dissepiments, which are usually geniculate. The attenuate axial ends of the major septa are curved vortically but irregularly, the irregularity being due to the expansion near the axis of some loculi or pairs of loculi, and the consequent crowding of the remaining ends; some of the axial ends are shorter than the others, and in crowded areas may abut on to the longer ones. In the adult stages most of the dissepiments are geniculate in transverse section, but some few are still curved. In the vertical section they are seen to be small, rather globose, and usually steeply inclined. The dissepimentarium is about 8 mm. wide at a diameter of 28 mm., and is equal to the length of the minor septa. The tabulae are usually incomplete, and the tabellae are then thin, small and not highly arched, and the tabular floors are low domes; when the tabulae are complete they are slightly saucered.

Remarks.—The species is known only from Lilydale in Victoria. It is closer to *M. graecense* (Penecke, 1894, p. 600, pl. viii, figs. 14, 15; pl. xi, figs. 5, 6) from the Coblenzian of Graz

than to the Frasnian genotype, for it has well-developed minor septa like *graecense,* whereas in *nobile* the minor septa have disappeared, leaving inosculating dissepiments.

Cystimorphs.

Cystimorphs are Rugose Corals in which the vertical skeletal elements are very much reduced, and the corallum is constructed almost entirely of arched horizontal skeletal elements, none of which extend completely across the lumen. The earliest cystimorphs occur in the Valentian of England (*Cystiphyllum cylindricum* Lonsdale, Smith, 1930, p. 300), Stage 7c α of Norway (*Cystiphyllum signatum* Lindström MS. Scheffen, 1933, pl. vi, figs. 3, 4) and the Clinton of North America (*Cystiphyllum spinulosum* Foerste, 1906, p. 321, pl. v, fig. 1, Bassler, 1915, p. 372). Thereafter cystimorphs, which can arise in many different lineages by the degeneration of the vertical skeletal elements (" cystiphylloid trend " Lang, 1938, p. 150), are common until the Upper Devonian, when only rare examples occur. None are known in the Carboniferous or Permian.

In England, *Cystiphyllum* (genotype *C. siluriense* Lonsdale) continues in the Wenlock and Ludlow (Lang and Smith, 1927, p. 455); *Goniophyllum* Edwards and Haime (Lindström, 1882, p. 42), a gonioid cystimorph with septal fragments which are linear and not acanthine, and *Microplasma* Dybowski, a fasciculate cystiphyllid (Lang and Smith, 1927, p. 478) occur in the Wenlock; *Hedströmophyllum* Wedekind (1927, p. 66), a cystiphyllid with very long trabeculae, has been recorded from the Aymestry limestone (Alexander, 1936, p. 106). These four genera also occur in the Middle and Upper Gotlandian of Gotland, with in addition *Aracopoma* Lindström (1882, p. 57), a cystiphyllid with remarkable epithecal trails, *Gyalophyllum* Wedekind (1927, p. 64) a cystiphyllid with a peripheral stereozone of closely packed holacanths in lamellar sclerenchyme, *Rhizophyllum* Lindström (1865; 1882, p. 22), calceoloid cystimorph with septal fragments which are linear and not acanthine, and *Holmophyllum* Wedekind (1927, p. 31), a cystimorph with deeply concave tabulae, and long, discontinuous trabeculae in the wide dissepimentarium of fine dissepiments. The Lower Ludlow (*fide* Lang and Smith, 1927, p. 476) of Tachlowitz in Bohemia contains numerous *Cystiphyllum* (Počta, 1902, p. 164). Cystiphyllids have been recorded from the Niagaran of America (Bassler, 1915, p. 371), and *C. cylindricum* occurs in China (Lindström, 1883, p. 73). *Rhizophyllum* occurs in the Upper Silurian of Australia), Etheridge, 1891, p. 201).

There is considerable diversity in the structure of these Silurian cystimorphs, and they probably belong to more than one family; *Goniophyllum,* for instance, may be related to the Phaulactidae.

Cystiphyllum itself has septa represented by holacanths, set in lamellar sclerenchyme which dilates the horizontal skeletal elements (Hill, 1936*a*, p. 211). It is difficult to distinguish between dissepiments and tabulae.

Several cystimorphs have been illustrated from Lower Devonian strata, but their generic relations are uncertain. These are three from the Eastern Alps (Charlesworth, 1914, pl. xxxii), three from the Eastern Urals (Tschernychew, 1893, pl. xiv, figs. 9, 18, 19), one from the Western Urals (Sochkina, 1937, pl. xv, figs. 5, 6), a phaceloid form from Maryland, U.S.A. (Swartz, 1912, pl. xxi, figs. 7-9), and two haploid species from Koněprus, Bohemia (Počta, 1902, pl. 117, fig. 3, pl. 105, figs. 1, 2).

Wedekind (1924) has illustrated several Couvinian cystimorphs under his new genera *Zonophyllum*, *Pseudozonophyllum* and *Lekanophyllum*. The detailed structure of the remnants of septa in these forms has not been described, but many of the dissepiments have truncated oval transverse sections; this character I have never seen in any Silurian cystimorph, but it is present in many Devonian cystimorphs. Stumm (1937, p. 440) placed three American Couvinian cystimorphs in *Mesophyllum* Schlüter, but they do not appear to me to be congeneric with the genotype, *Mesophyllum defectum* Schlüter as figured by Wedekind (1925, pl. 13, fig. 76). Two of them show a marked distinction between dissepimentarium and tabularium; none show any trace of the fossula which characterizes the *Mesophyllum-Mochlophyllum* group. None of the Devonian cystimorphs which I have examined show holacanths; but Wedekind (1937, pl. vii, fig. 1) gives a diagram which possibly indicates that true *Cystiphyllum* with holacanths existed at the base of the Couvinian.

In the German Givetian cystimorphs it is apparent that the septal remnants are of septa whose trabeculae were monacanths arranged in single radial series, close enough together in each series to form a septum pinnately fibrous about its median plane. Amongst them is an easily distinguishable group in which the septal remnants are visible only in successive zones of skeletal dilatation; each zone of dilated tissue is deposited on one old skeletal floor, and the dilatation is greatest in the middle of the floor, and decreases towards the periphery; as the calical floor is conical in all these forms, the zone of dilatation is conical also. This group includes *Cystiphyllum pseudoseptatum* Schulz (1883, pl. xxiii, figs. 2-4), and possibly also part of *Cystiphyllum vesiculosum* Goldfuss; Wedekind (1925) and Wedekind and Vollbrecht (1931) have figured it under the generic names *Lythophyllum*, *Nardophyllum*, *Paralythophyllum* and *Plagiophyllum*. The cystimorphs *Mesophyllum defectum* Schlüter (see Wedekind's figure, 1925, pl. 13, fig. 76), *Cosmophyllum* Vollbrecht (1922) and *Atelophyllum* Wedekind (1925, p. 37)

seem to me to be a different group; they are without the successive cones of septal dilatation, and the remnants of septa have greater radial extension, and are in the form of "bars" at the periphery. *Diplochone* Frech (1886) from the boundary between the Middle and Upper Devonian has no septal remnants but has a very narrow dissepimentarium of elongate dissepiments, and a wide tabularium of large concave plates.

In the Upper Devonian, cystimorphs occur in Western Australia (Hill, 1936*b*, p. 27), and in Canada (Fenton and Fenton, 1924, p. 41).

"Cystiphyllum" sp.

(Plate XV, figs. 4, 5.)

One weathered fragment of a trochoid corallum was obtained from Loyola by Miss E. A. Ripper (Melbourne University, Geology Department No. 620). It increases in diameter from 15 mm. to 20 mm. in a distance of 12 mm. The calice and apex were not preserved and the epitheca was weathered off. Horizontal skeletal elements are dominant; they are distally arched and are roughly divisible into a peripheral zone of smaller plates steeply inclined from the periphery, about one-third as wide as the radius of the corallum, and an axial zone of larger plates, whose inclination becomes less steep towards the axis, where they are arched about a horizontal plane. They are without any regularity of position. One or two are truncated ovals in transverse section. They are dilated in zones, each zone presumably at the position of a past calice, and the dilatation appears to lessen from the periphery to the axis. The dilated tissue is fibrous, the fibres lying at right angles to the curvature of the plate. Individual trabeculae can be distinguished in it only near the periphery, where they are seen in vertical section to be about 0.5 mm. in diameter, and to consist of fibres directed upwards and outwards from their axes; that is, they are monacanths (Hill, 1936*a*, p. 194). In transverse section the trabeculae may sometimes be continuous from one dissepiment to the next, so that short radial fragments of septa are present, about 0.5 mm. thick.

Remarks.—The fragment differs from the Silurian Cystiphyllids and resembles Devonian cystimorphs in having monacanthine and not holacanthine trabeculae. It differs from the Lower Givetian Cystiphyllids described by Wedekind (1925, p. 32), as *Lythophyllum* in having the dilatation of its horizontal skeletal elements increasing from the axis outwards. Truncated oval sections of dissepiments are common in Devonian cystimorphs, and one or two occur in this Loyola specimen. The specimen cannot be regarded as of any great significance for the determination of the age of the limestone, but it indicates the Devonian rather than the Silurian.

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Plate XIII.

Rugose Corals from Lilydale and Canada.

All figures, except figures 1, 8, and 9, approximately × 2 diameters.

Fig. 1.—*Prismatophyllum chalkii* (Chapman). Holotype, from Lilydale. Chapman Collection. Natural size.
Fig. 2.—The same. Topotype 626, Melbourne University Geology Department Collection. Transverse section.
Figs. 3-4.—The same. Topotype 628-9, Melbourne University Geology Department Collection. Oblique section.
Fig. 5.—The same. Topotype 627, Melbourne University Geology Department Collection. Vertical section.
Fig. 6.—*Prismatophyllum stevensi* (Chapman), holotype. Vertical section 624, Geological Dept., Melbourne University. Lilydale.
Fig. 7.—The same. Transverse section, 625, same collection.
Fig. 8.—*Mictophyllum nobile* Smith, holotype, Geol. Surv. Canada Colln. Frasnian, Mackenzie R. Canada. Transverse section. × 1½ diameters.
Fig. 9.—The same. Vertical section. × 1½ diameters.

Plate XIV.

Rugose Corals from Lilydale.

All figures approximately × 2 diameters.

Fig. 1.—*Lyrielasma subcaespitosum* (Chapman), holotype, 1731, National Museum, Melbourne. Transverse section.
Fig. 2.—The same. Transverse section.
Figs. 3*a*, *b*.—The same. Vertical sections.
Figs. 4*a*, *b*.—The same, topotype F 1329*a*, Australian Museum, Sydney. Vertical and transverse sections.
Fig. 5.—The same, topotype F 1329*b*, Australian Museum, Sydney. Vertical section.
Fig. 6.—The same. Transverse section.
Fig. 7.—*Mictophyllum creswelli* (Chapman), topotype F 1146, Australian Museum. Transverse section.
Fig. 8.—The same. Vertical section.
Fig. 9.—The same, topotype 630, Melbourne University Geology Department Collection. Vertical section.
Fig. 10.—The same, topotype F 1242 Australian Museum, Sydney. Vertical section.
Fig. 11.—The same. Transverse section.

Plate XV.

Rugose Corals from Loyola.

The figured sections and the specimens from which they were cut are in the Geology Department, University of Melbourne.

All figures approximately × 2 diameters.

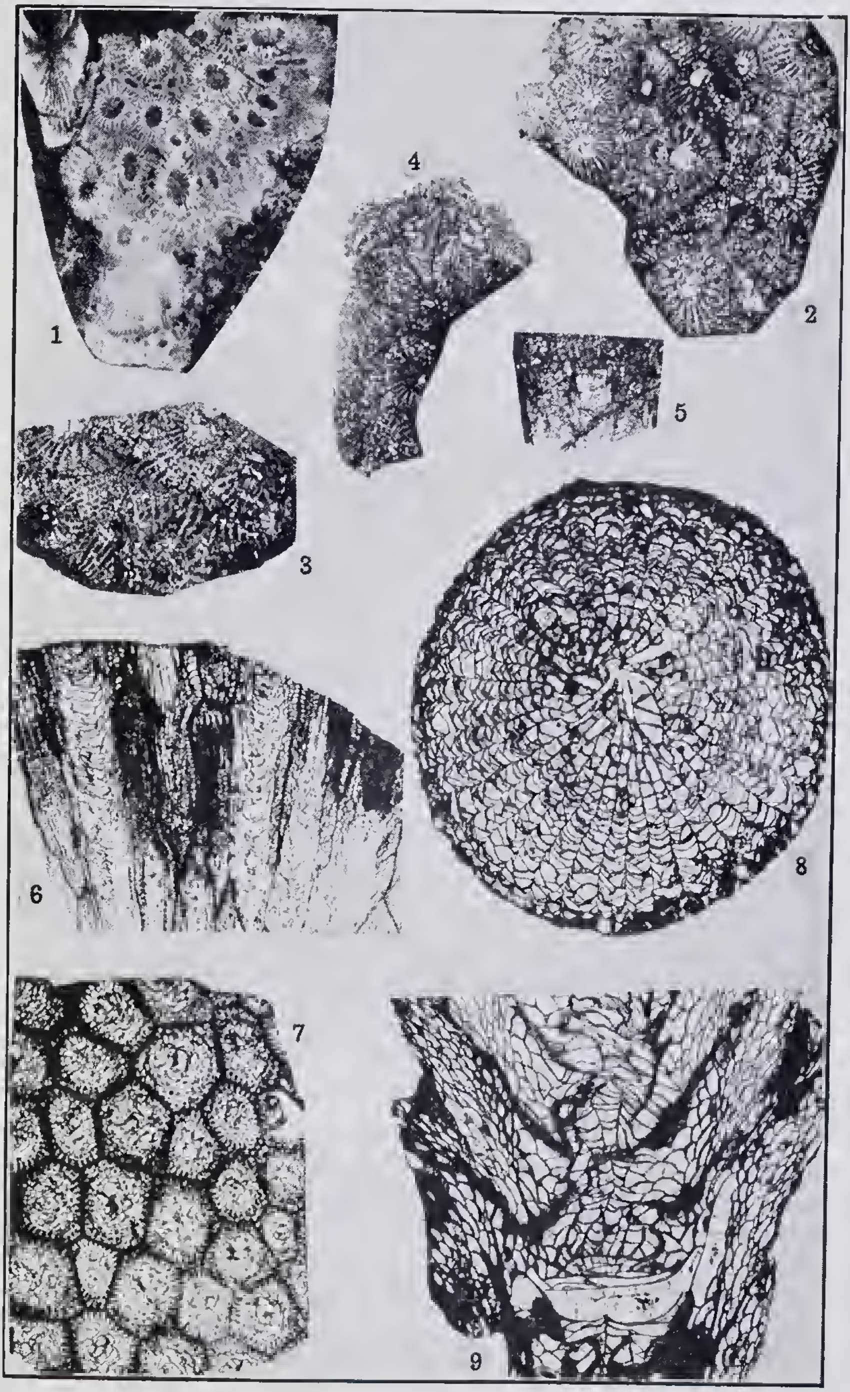
Fig. 1*a*.—*Acanthophyllum mansfieldense* (Dun), topotype. Transverse section 608.
Fig. 1*b*.—The same. Lighter print of central part of fig. 1, to show the waving and carinae of the septa.
Fig. 2.—The same. Vertical section 609.
Fig. 3.—The same, topotype. Transverse section 610.
Fig. 4.—"*Cystiphyllum*" sp. Transverse section 620*a*.
Fig. 5.—The same. Vertical section 620*b*.
Fig. 6.—*Lyrielasma subcaespitosum* (Chapman), transverse section 621.
Fig. 7.—The same, 622.
Fig. 8.—*Loyolophyllum cresswelli* Chapman, topotype. Transverse section 616.
Fig. 9.—The same. Oblique section 617.
Fig. 10.—The same. Vertical section 618.
Fig. 11.—The same. Transverse section 619.
Fig. 12.—Gen et sp. indet. Oblique section 623.

Plate XVI.

Rugose Corals from Loyola.

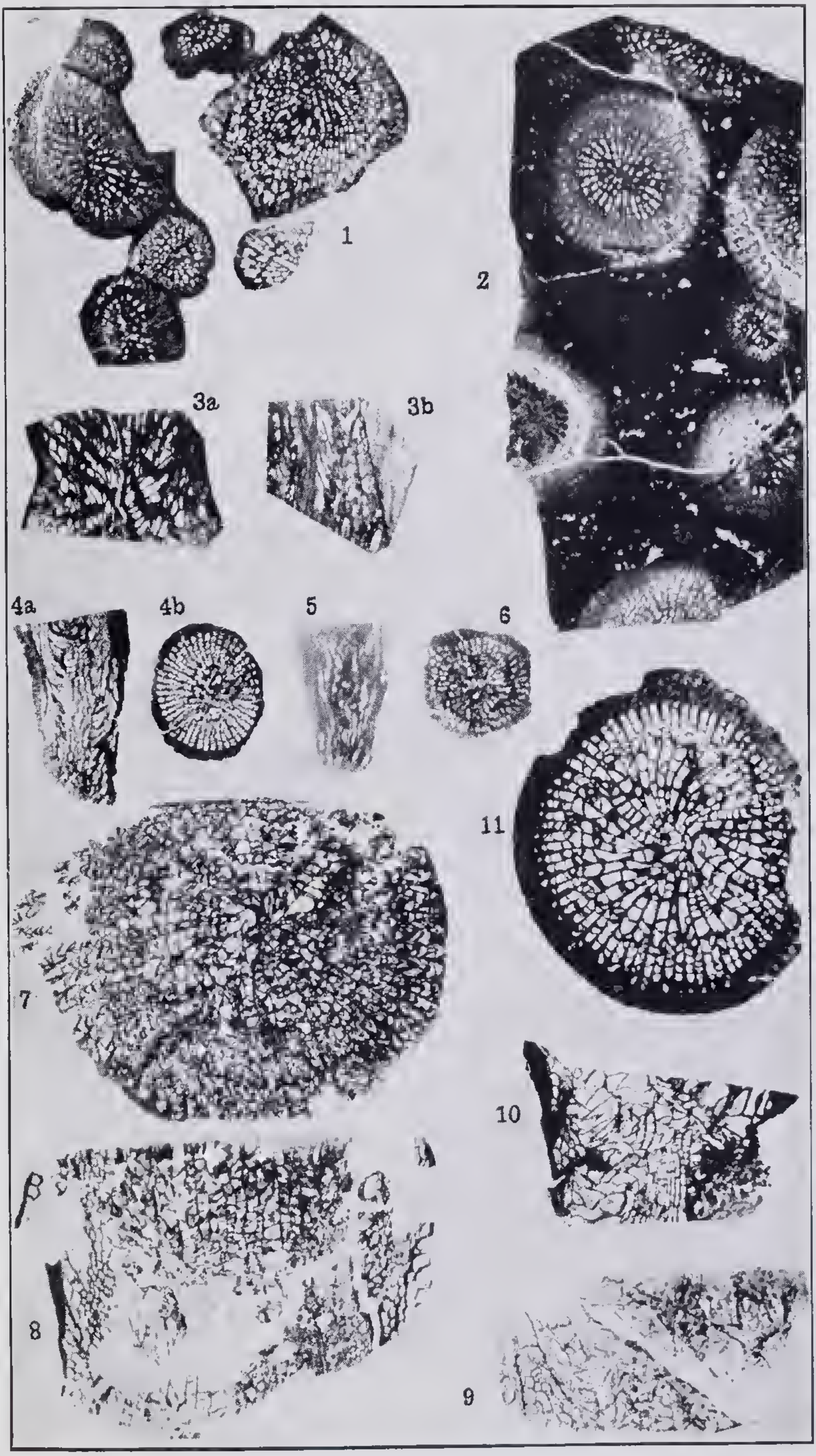
All figures approximately × 2 diameters.

Fig. 1.—*Phillipsastraea speciosa* Chapman, holotype, 2487 Geological Survey of Victoria. Vertical section 1388, National Museum, Melbourne.
Fig. 2.—The same. Transverse section 1387, National Museum, Melbourne.
Fig. 3.—The same, topotype, University of Melbourne, Geological Dept. Transverse and part of a vertical section (611) through corallum with septa withdrawn from the tabularium.
Fig. 4.—The same. Vertical section 612.
Fig. 5.—*Phillipsastraea* sp. indet., 2491, Geological Survey of Victoria. Transverse section 1374, National Museum, Melbourne.
Fig. 6.—The same. Oblique section 1375, National Museum, Melbourne.
Fig. 7.—*Thamnophyllum reclinatum* sp. nov., holotype, R 25186, British Museum (Natural History), London. Transverse section.
Fig. 8.—The same. Vertical section.
Fig. 9.—*Trapezophyllum elegantulum* (Dun), topotype of genotype, University of Melbourne, Dept. of Geology. Transverse section 613.
Fig. 10.—The same. Vertical section 614.
Fig. 11.—The same. Vertical section 615.

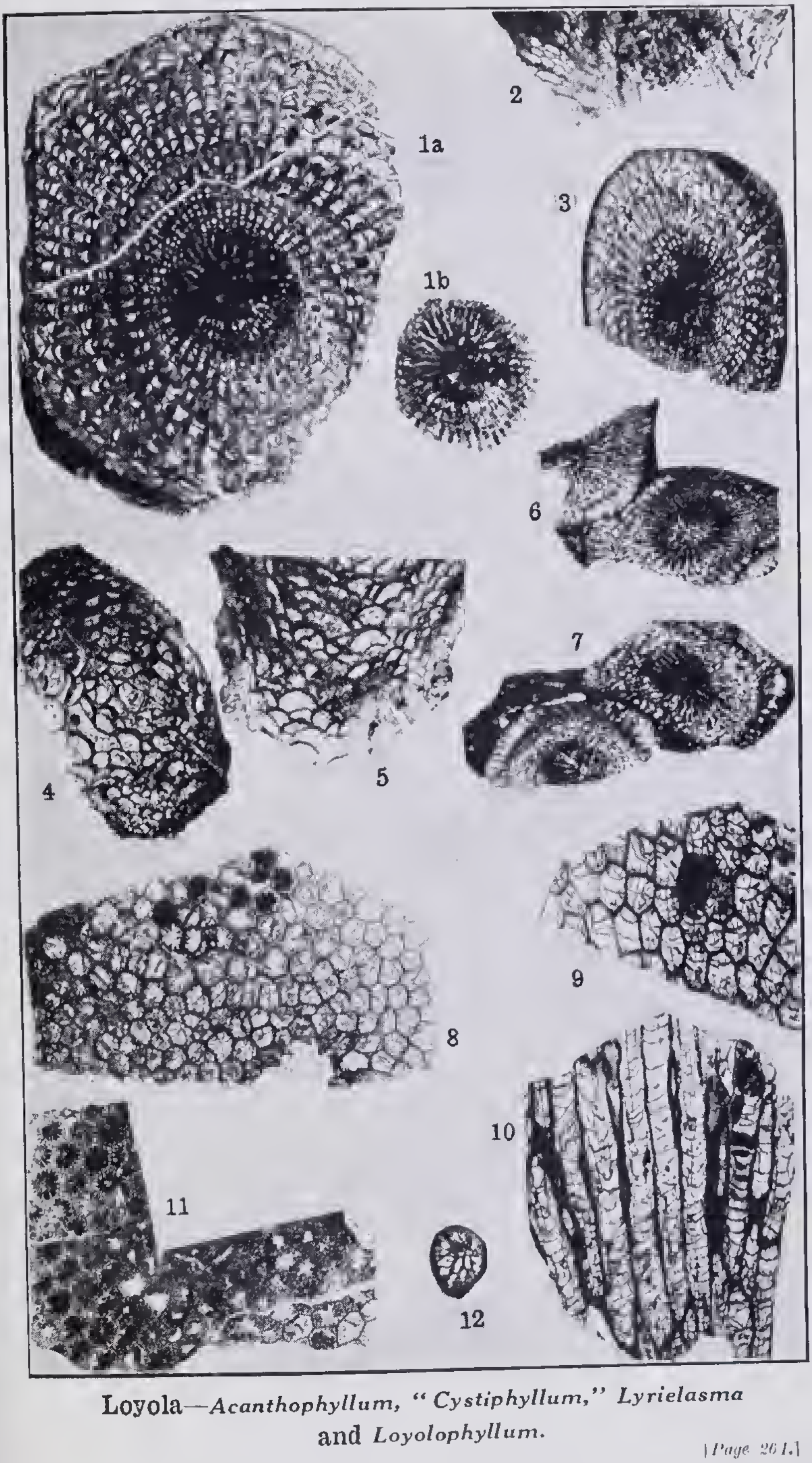


Lilydale—*Prismatophyllum.*
Canada—*Mictophyllum.*

[Page 257.]

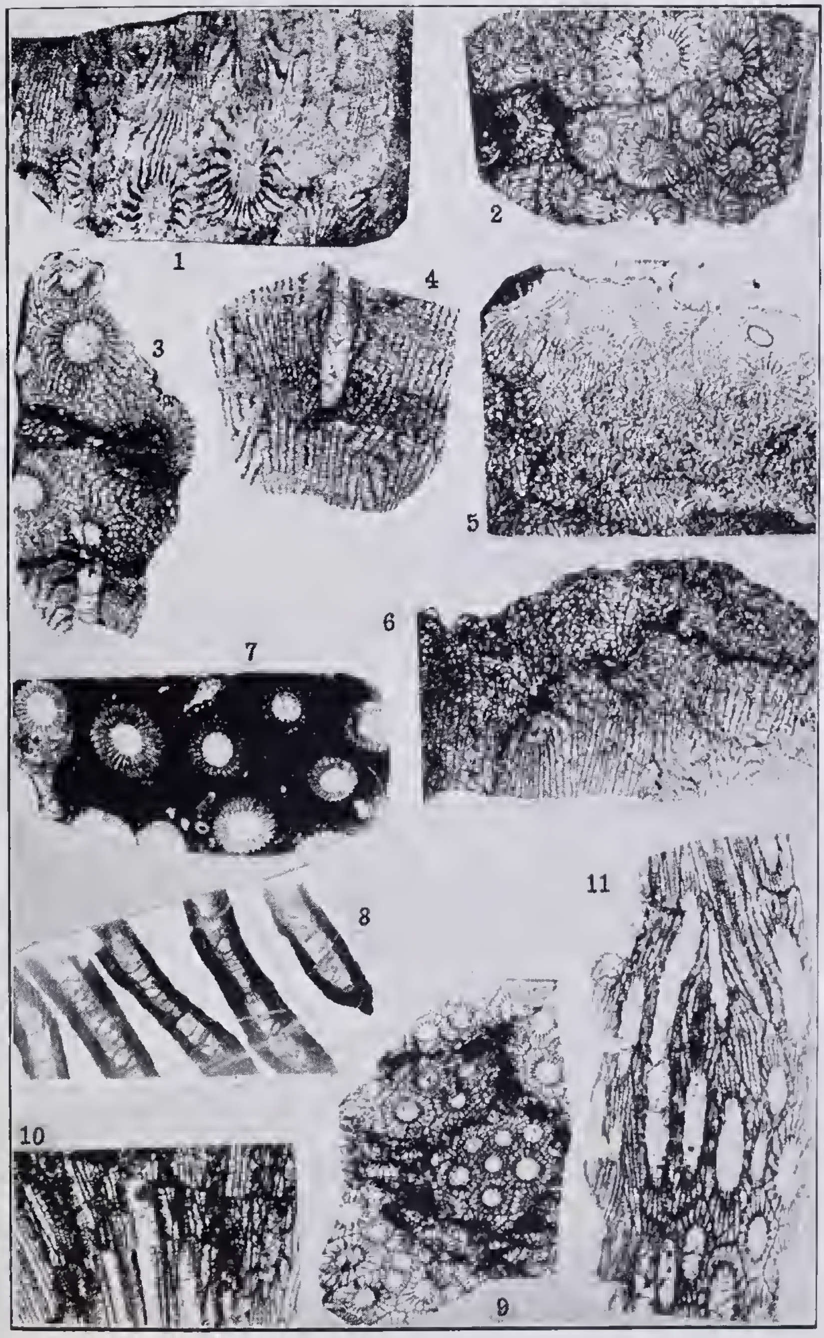


Lilydale—*Lyrielasma* and *Mictophyllum.*



Loyola—*Acanthophyllum*, "*Cystiphyllum*," *Lyrielasma* and *Loyolophyllum*.

[*Page* 261.]



Loyola—*Phillipsastraea, Thamnophyllum, Trapezophyllum.*

[Proc. Roy. Soc. Victoria, **51** (N.S.), Pt. II., 1939.]

Art. XII.—*Studies on the Australian Clavariaceae. Part II.*

By STELLA G. M. FAWCETT.

[Read 8th December, 1938; issued separately, 24th July, 1939.]

Genus **Clavaria** (*continued*).

In a previous contribution (Proc. Roy. Soc. Vic., n.s. LI. (1), pp. 1-30), the groups 3, 4, 7, 8, and 9 of this genus, as classified by Coker, were dealt with. In this part it is proposed to describe the groups 1, 2, 5, and 10.

Group 1 (incomplete).

Clavaria aurantia Cke et Mass. Grev. XVI., 33, 1887.

(Plate XXII., fig. 3, text fig. 1a.)

Plants simple, solitary, 6–9 cm. high and 2–4 mm. broad. Stem distinct but not sharply delimited, whitish, rather woolly, 1.5–2 cm. long. Club cylindrical, slightly thickened upwards, smooth, except for a few longitudinal rugae, tips bluntly rounded. Colour Orange Chrome. Flesh solid, somewhat fibrous, colour near to Apricot Yellow, pliable, not at all brittle. Taste and smell, none, or very mild.

Spores copious, white, smooth, sub-globose to elliptical. 3.9–6.1 × 6.2–7.7 μ with one large guttule. Locality: Turton's Pass, Tanybryn; on ground on hillsides.

This species may be distinguished by its deep dark orange colour, solitary habit and elongated, cylindrical clubs. It is recorded from only one locality in Victoria.

Coker has examined a plant of this species (Bresadola Herb. No. 50) and gives a spore measurement which agrees very closely with that of the plant as we know it. He points out the similarity between this plant and *C. aurantio-cinnabarina* Schw. Cooke's illustration of *C. aurantia* suggests our plant in shape and habit, but is rather lighter in colour.

Clavaria caepicolorosa n. sp.

(Plate XIX., figs. 2, 3, 4, text fig. 1b.)

Plantae simplices, gregariae, raro caespitosae, 4–10 *cm. alt,* (*nonnunquam ad* 15 *cm.*), 5–6 *mm. latae* (*nonnunquam* 1.5 *cm. latae*). *Stirps cylindrica, octava pars ad quarta pars plantae altitudine cum radicibus non profundis levis aliquantum fulgens multo angustior quam clava, nonnunquam maxime distincta tomentosa ad basem. "English Red" aut minus rubra.*

Clava valde cylindrica, aliquantum flexuosa, plerumque levis, sed nonnunquam rugulosa et dilata. Apices obtusae et rotundae nonnunquam dilatae. Colour "Onion Skin Pink" juvenis, postaea "Japan Rose," "Congo Pink," "Terra Cotta," "Orange Vinaceous." Caro solida magis colorosum et magis translucens juxta hymenium, in media parte clavae mollis et postea exesa Fragilis facile fracta cum flecta, in aetate cava et saepe exese ab vermiculis. Sporae albae, subglobosae, 7–9 μ latae, leves cum minuto apiculo et una magna gutta.

Hab. ad terram.

Loc. Fairyland, Apollo Bay.

Plant simple, gregarious, rarely caespitose, height 4–10 cm. (sometimes to 15 cm.), 5-6 mm. broad (sometimes to 1.5 cm. broad). Stem cylindrical, $\frac{1}{8}$–$\frac{1}{4}$ the height of the plant, not deeply rooting, smooth, slightly polished, much narrower than the club, sometimes sharply delimited, hairy at the base, English Red or lighter in colour.

Club stoutly cylindrical, somewhat flexuous, generally smooth but sometimes rugulose and flattened. Tips blunt and round, sometimes flattened. Colour Onion Skin Pink when young, later Japan Rose, Congo Pink, Terra Cotta or Orange Vinaceous. Flesh solid, darker and more translucent just below the hymenium; in the centre of the club, loose, soft and fibrous, tending to tear apart into hollows. Brittle, splintering or snapping with a clean break when bent, hollow in age and frequently attacked by grubs. Spores white, sub-globose, 7–9 μ in diameter, smooth, with a minute apiculus and a single large guttule. Habitat—on ground in gullies, on cliffs and among grass in cleared land. Locality: Fairyland, Apollo Bay.

This is a well-marked species, obviously related to *C. aurantia*. In the field it can be recognized by its colour, stout, more or less cylindrical, clubs and constricted stem.

CLAVARIA ACUTA Fr. ex Sow. Sow, Engl. Fungi, pl. 333, 1803.

?*C. falcata* Pers. Comm. p. 81 (213), 1797.

(Text fig. 1 (D).)

Plants simple, single or in small caespitose clumps, between 2 and 5 cm. high. Stem equal to about one-third the plant or less, translucent, shining, glistening with minute, scurfy projections. Club thickened upwards, often expanded at the tip and bluntly bilobed, sometimes cylindrical, but more often flattened Flesh solid, translucent, soft and very fragile, breaking cleanly when even slightly bent. Taste and odour none. Colour, pure milky white.

Spores white, smooth, sub-spherical but with one side definitely flattened and with a distinct apical mucro, 7–8.5 × 8–10 μ. Growing on bare ground in gullies or among moss in heathland.

Localities: Otway Forest, Cockatoo, Mt. Evelyn, Phillip Island. Not previously recorded for Australia.

This species can be readily recognized by the pure white colour, translucent, shining stem, extreme fragility and by the sub-spherical spores which show one flattened side. It is obviously closely related to *C. rosea* (sensu Cotton and Wakefield) and to *C. luteostirpata.*

Clavaria luteostirpata n. sp.

(Plate XIX., fig. 5, text fig. 1 (o).)

Plantae simplices, singulae, aut caespitosae in parvis fascibus, gregariae, 3–7 cm. altae, stirps aequalis ad tertiam partem planti, distincta sed in hymenium mergens, teretis, levis et fulgens. "Empire Yellow" cum radicibus non profundis. Subiculum non obvium. Clava 2–5 cm. longa, 2–5 mm. lata si cylindrica, 3–4 mm. si dilata, recta aut magis sinuosa, saepius cum apice latiore, nonnumquam compressa et raro cum uno aut duobus cornibus in apice. Apices obtusae, leniter spiculatae. Colour "Pinard Yellow," magis translucens cum juvenis. Caro clavae similis coloris quam exterior pars, mollis, fragilis, stirps cum cortice cartilaginosa sed mollior ad interiorem partem.

Sapor et odor nullus aut blandissimus.

Sporae albae, leves, sub-globosae, cum apiculo prominenti, 6.2–9 × 7.3–10 μ *av.* 7.5–8.8 μ, *cum magna gutta.*

Hab. ad terram. Loc. Cockatoo.

Plants simple, solitary or caespitose in small groups, gregarious, height 3–7 cm., the stem equal to one-third of the plant, distinct, but grading into the hymenium, terete, smooth and shining, Empire Yellow, not deeply rooting, subiculum not obvious, club 2–5 cm. long, 2.5 mm. wide if cylindrical, 3–4 mm. if flattened, straight or rather flexuous, usually broader at the apex, sometimes compressed and rarely with one or two antler-like branches at the apex. Tips bluntly pointed, gently tapered. Colour Pinard Yellow, rather translucent when young. Flesh of club, concolorous, soft, brittle, stem with a cartilaginous rind but softer in the centre. Taste and odour none or very mild.

Spores white, smooth, sub-globose, with a prominent apiculus, 6.2–9 × 7.3–10.4 μ, average 7.5–8.8 μ, with a large guttule. Habitat—on ground in gullies. Localities: Cockatoo, Otway Forest.

This is a very well-marked species and can be readily distinguished by the shining yellow stem and paler, rather translucent club. It is near to *C. appalachiensis* Coker but differs in its smooth hymenium and larger spores. It is obviously related to *C. rosea* (sensu Cotton and Wakefield) as the spores are very similar and this plant has also a shining stem and paler club. The two species are very often found growing together.

GROUP 2.

CLAVARIA FUSIFORMIS Fr. ex Sow. Sow. Engl. Fung., pl. 234. 1799.

C. fasciculata Villars. Hist. Plant. Dauph., 3: 1052, 1789.
C. platyclada Pk. Bull. Torrey Bot. Club, 23: 419, 1896.
C. compressa Schw. Trans. Am. Phil. Soc. II., 4: 182, 1832.
(Not *C. compressa* Berk. or *C. compressa* Schroet.)
C. ceranoides Pers. Syn. Met. Fung., p. 594, 1801.

(Plate XVII., figs. 4 and 5, text fig. 1 (L).)

Plants simple, usually growing in dense clusters, 4–6 cm. high, and 2–4 mm. wide, solid, sometimes cylindrical but more often flattened, at times thickened upwards, and spatulate at the tips, again thickened to about the middle and tapering to a blunt point at the apex. Base not distinct. Flesh firm, paler than the surface, opaque, solid, (not often with a hollow in the centre as in American and European plants). Moderately brittle, not snapping with a clean break when bent. Colour Light Cadmium or Empire Yellow, Capucine Buff in age. Taste varies from mild to bitter, smell none. Spores 5–7 μ diameter, globose, smooth with a very distinct abrupt apiculus, with or without a large central gutta. Spore deposit yellow or white (this character has been observed in American plants, but the spores show no differences microscopically). Habitat—on ground in open or sheltered places, sometimes on buried sticks. Widespread in Victoria. Not previously recorded for this State. There is a multiplicity of species of simple yellow *Clavarias* in Victoria, some of which are difficult to determine accurately, but among them *C. fusiformis* can be readily identified by the following characters:—

1. Fascicled habit.
2. Bright, opaque, egg-yellow clubs.
3. Blunt tips and generally flattened clubs.

CLAVARIA VERMICULARIS Fr. ex Micheli. Fr. Syst. Myc. 1, 484, 1821.

Micheli Nova Plant Gen., p. 209, pl. 87, fig. 12, 1729.
(as *C. vermiculata*).
C. cylindrica Bull. Herb. Fr., p. 212, pl. 463, fig. 1, 1789.
C. fragilis Holmsk. Beata Ruris, 1: 7, pls. 2 and 3, 1790.
C. gracilis Sow. Engl. Fung., pl. 232, 1797.
C. eburnea Pers. Syn. Met. Fung., p. 603, 1801.
?*C. canaliculata* Fr. Obs. Myc. 2: 294, 1818.
(not *C. canaliculata* Ehrenb.).
C. alba Pers. Myc. Europ., 1, 175, 1822.
(not *C. alba* Pers. ibid., p. 161).
C. pistilliforma Pers. Myc. Europ., 1: 183, 1822.
?*C. corynoides* Pk. Rept. N.Y. St. Mus., 31: 39, 1879.
C. nivea Quel. Assoc. Francaise, p. 3, pl. 3, fig. 11, 1901.
(22nd supplement to Champ. Jura, etc.).

(Text fig. 1 (E).)

Plants most often gregarious, sometimes single. Simple or very sparingly branched, up to 4 cm. high and 2–3 mm. broad. Stem not distinct, clubs pure white, thickened upwards, bluntly pointed. Flesh, white, rather translucent, very brittle. Taste and smell, none. On drying the plants become Isabella Colour and on being placed in water regain their former shape instantly.

Spores, globose, smooth, hyaline, minutely apiculate, 3–5 × 3–4 μ. Basidia with four sterigmata. Habitat—on ground in gullies. Locality: Dandenong Ranges.

Cooke records this plant for Victoria but gives the spore measurement as 8 × 6 μ. If these spore measurements are correct it is possible that he had either *C. cristata* (*rugosa* form) or *C. acuta*. Coker calls this plant *C. vermiculata* Micheli but according to the Rules of Botanical Nomenclature, the Friesian name *C. vermicularis* is valid.

This species can be distinguished from *C. acuta* by its more slender habit, indistinct stem, smaller spores and by the fact that it tends to grow in groups. Dried plants of *C. acuta* do not instantly regain their shape on moistening.

Clavaria corallino-rosacea Clel. Aust. Fungi: Notes and Descriptions, No. 8. Trans. S.A. Roy. Soc., Vol. LV., 1931, pp. 152-160, 1931.

(Plate XXII., figs. 5 and 6, text fig. 1 (B).)

Plants simple, occasionally antlered, growing in large colonies, but the bases usually separate. Height up to 12 cm., commonly 6–9 cm., breadth up to 5 mm., commonly 2–4 mm.

Stem not distinct, rather smoother than the club, slightly polished. Clubs broadest in the middle, attenuated above and below, tapering to a blunt point at the apex, generally flattened and ribbon-like, flexuous, quite frequently cylindrical and straight. When young, smooth, later developing longitudinal wrinkles. Flesh solid, concolorous beneath the hymenium, paler in the centre of the club. Taste slight, pleasant and sweet, similar to that of *C. pulchra;* smell similar, persisting in dried plants. Colour, Coral Pink, Light Coral Red, Coral Red, fading in age, and paler and more yellowish in underground parts.

Spores, white in thin layer, same colour as the club when scraped together, 7–10 × 3–4.4 μ. Once or twice guttulate, smooth, obliquely pip-shaped, pointed at both ends when mature, rounded at the distal end in youth. Basidia with 2 or 4 sterigmata Hyphae 4–5 μ wide, containing many oil droplets. Habitat—on ground, very widespread in Victoria.

Cleland first recorded this plant as *C. rosea* but later described it as a new species. The plants he described are generally smaller and have shorter spores than the Victorian plants. In addition, he describes the spores as "somewhat pear-shaped, 6 × 3.4–4 μ". Cleland examined a collection of the Victorian plant and says that it is undoubtedly *C. corallino-rosacea.*

He records the plant for New South Wales and South Australia but, although widespread in this State, it has not been previously recorded here. A plant, No. 249, in the Rodway Herbarium is probably this species. It shows no spores.

Clavaria pulchra Pk. Rept. N.Y. St. Mus. 28: 53, pl. 1, fig. 10, 1876.

C. angustata Pers. (Sense of Schw.) Comm., p. 72, 1797.
C. persimilis Cotton, Trans. Brit. Myc. Soc. 3: 182, 1909.

(Plate XIX., fig. 1, text fig. 1 (G).)

Plants gregarious, caespitose in small clusters, or occasionally single. Up to 12 cm. high, 1 cm. broad and 4 mm. thick. Sometimes cylindrical with a bluntly pointed tip, more often flattened and channelled, usually flexuous; rudimentary branches often present. Clubs thickened upwards, stem smooth, glabrous, narrower than the club, but not sharply delimited. Hymenium smooth or with a few longitudinal wrinkles. Flesh soft, whitish in the centre, rather fibrous, pliable, not brittle, but breaking when bent upon itself. Taste and odour, sweet, like that of *C. corallino-rosacea.* Colour, Cadmium Yellow, Flame Scarlet to Orange Chrome, Capucine Yellow to Deep Chrome, Light Cadmium to Pinard Yellow. Base whitish for a variable distance upwards. Spores, oblong-elliptical, with a prominent oblique mucro, white, 4.2–5.3 × 6.7–7.8 μ. Habitat—on ground in forest country. Widespread in Victoria. Not previously recorded for Australia.

This plant shows most of the characters of *C. pulchra* as understood by Coker but the spores, although similar in shape, are narrower than and show a greater range in length than the American plants.

C. pulchra can be distinguished from *C. fusiformis* by (1) oblong spores, (2) deeper orange colour, (3) rather more irregular clubs, (4) lack of strongly fascicled habit.

Group 5.

Clavaria miyabeana S. Ito. Trans. Sapp. Nat. Hist. Soc., Vol. XI., Pt. 2, p. 72, 1930.

(Plate XXIII., text fig. 1 (J).)

Plants commonly densely caespitose, sometimes in loose clusters, rarely single, 3–14 cm. high, 0.5–7 cm. broad. The smaller plants are generally simple and club-like, at first almost cylindrical, later flattened, thickened upwards, and with a distinct broad groove on either side, edges rounded, apex broadly obtuse or showing one or two rudimentary antler-like branches. Larger plants assume very varied and fantastic shapes, very much flattened and expanded laterally with a sinuous, often inrolled

margin and with many fine longitudinal striations; or knobbed and irregular at the apex, tapering to a slender base; or forming a dense convoluted, compact mass. Base not sharply delimited, often deeply rooting, sometimes attached to buried sticks, concolorous or whitish. Flesh, solid, rather loose in irregular specimens, paler than the surface. Taste and smell, slight and pleasant. Colour: Grenadine and Grenadine Red.

Basidia with two or four sterigmata, spores white in mass, globose, smooth, with a well-marked apiculus and a large central gutta, 6.3–8.2 × 6.5–8.5 μ. Habitat—on sandy soil under bracken and on peaty soils in swampy areas. Localities: Hordern Vale, Hedley.

Not previously recorded for Australia. This is easily the most spectacular species of Clavaria that occurs in Victoria and can be easily recognized by its brilliant, orange-red colour, by its large size and generally contorted clubs. It agrees very closely with the description of the type. It is known to a number of people at Hedley as the "Flame Fungus" and it appears worth while to retain this as the vernacular name for the species as it is so descriptive. This species, particularly in those specimens which are very much flattened and expanded, apparently shows affinities with *Craterellus* as do *Clavaria pistillaris* and *Clavaria ligula*.

Clavaria pallidorosea n. sp.

(Plate XX., fig. 2, text fig. 1 (q).)

Plantae singulae aut gregariae in parvis fasciculis, 6–11 *cm. alt,* .5–1 *cm. lat. Basis rotunda, saepe cava, brevis, cum radicibus non ex profundo surgentibus, junctio cum hymenio inaequalissima. Clava saepissime latescens et torquens, cum multis rugis in longitidinem, nonnullae latis. Apices obtusae, rotundae, aut latescentes et se dividentes in duos ramos cornutos. Colour "Bittersweet Pink" cum nota crocea in apice. In aetate aut sicca magis lutea. Caro solida "Grenadine Pink", opaca, fragilis facile fracta flectendo, nonnumquam cava ad basem. Sapor et odor dulcis, similis ad C. corallino-rosacea. Interior pars habet tenues hyphas inter se innectentes. Basidia clavata, cum duobus aut quattior sterigmatis. Sporae leves, in massa albae, globosae cum apiculo recto et prominenti* 4.8–6.9 × 5.1–6.9 μ (*av.* 5.4 × 5.9 μ), *una magna gutta. Hab. ad terram carbonaceam. Loc. Labertouche.*

Plants single or gregarious in small clusters, 6–11 cm. high, 0.5–1 cm. broad. Base rounded, often hollow, short, not deeply rooting. Junction with hymenium very irregular. Club typically flattened and twisted, finely rugose, with a few broad longitudinal wrinkles. Tips obtuse and rounded or flattened and divided into two antlered branches. Colour: Bittersweet Pink, with a hint of orange at the tip, creamy yellow in age or on drying. Taste and smell, sweet and pleasant, rather like *C. corallino-rosacea*

Flesh solid, Grenadine Pink, opaque, brittle, snapping when bent, sometimes becoming hollow towards the base. Internal structure of fine, slightly interwoven hyphae. Basidia clavate, with two or four sterigmata. Spores smooth, white in mass, globose, with a prominent, straight apiculus, 4.8–6.9 × 5.1–6.9 μ (av. 5.4 × 5.9 μ) with one large central gutta. Habitat—on burnt ground. Locality: Labertouche.

The colour and habit of this plant suggests *C. pistillaris*, but the spores of the latter are much larger (9–18 μ long). It can be readily distinguished in the field by its stout habit, orange-pink colour, and globose spores. It is obviously related to *C. Miyabeana*, but differs in colour, is more regular in habit, and has smaller spores.

Group 10 (incomplete).

Clavaria sinapicolor Clel. Aust. Fungi Notes and Descriptions No. 8. Trans. Roy. Soc. S.A., Vol. LV., 1931, pp. 152-160.

(Plate XXI., figs. 1-7, 9, text fig. 1 (c).)

Plants massive and branched, up to 12 cm. high and 9 cm. broad, growing singly, or small and slender, occasionally growing singly but generally in extensive clumps, either free or partially fused at the base. It is obvious that large single plants have arisen through the fusion of several or many individuals, as in almost any large colony of this plant a series of plants showing progressive stages of complexity due to the fusion of separate individuals can be found.

Base of simple plants, cylindrical, somewhat pointed below, branching dichotomously near the ground into two branches which are not markedly different from the stem in size. These primary branches usually elongate a great deal before branching in a similar fashion, and after this may branch once or twice to form the ultimate tips which are long, upright or flexuous, and cylindrical, tapering to blunt tips. Axils rounded, but trend of the branches upright, a furrow descending from either side of each axil, branches cylindrical but somewhat flattened at each axil.

The branching of the complex plants is similar to that of the simple ones. The trunk may be slender, vertical rugae indicating that the plant is the result of the fusion of several; or if stout, composed of many fine compacted stems. Colour, Naples Yellow, Mustard Yellow, Straw Yellow, Light Orange Yellow. Flesh white, or pale creamy yellow, solid. Taste mild, smell sweet, rather like that of broome or gorse, strong in age. Spores ochraceous, elliptical, moderately rough, with an oblique apiculus 3–4.5 × 6–8–10 μ. There is some indication that on the whole large plants produce longer spores than small plants.

This is a very abundant species in Victoria and has been collected between March and November. It can be distinguished by the generally tufted habit, yellow colour and upright, cylindrical branches with somewhat flattened axils

Clavaria fennica Karst. Nat. Sällsk. Faun. et Flora Fenn. 9, 372, 1868 (not *C. fennica* Karst. Bidr. Finl. Nat. Folk. 48: 47, 1889. = *C. decolorans* Karst. Symbolae ad Myc. Fenn. 32: 10, 1893.).

?*C. rufo-violacea* Barla Champ. Nice, p. 87, pl. 41, figs. 3-13, 1859.
C. fumigata Pk. Rept. N.Y. St. Mus. 31, 38, 1879.
Ramaria versatilis Quel. in Assoc. Fr. Av. Sci. Compte Rendu 22, Pt. 2, 489 (1893), 1894.
C. versatilis Quel. (Boud. and Galzin) Bull. Soc. Myc. Fr. 26: 214, 1910.
Clavariella versatilis (Quel.) Maire Bull. Soc. Myc. Fr. 30: 218, pl. 9, figs. 1, 1*b*, 1*s*, 1914.

(Plate XVIII., fig. 2, text fig. 1 (M).)

Plant branched and bulky up to 5 × 5 × 10 cm. Base typically stout and distinct, more or less cylindrical, often bulbous, attached to the soil by a few inconspicuous fibres. Branches arising as in *C. botrytis*, i.e., beginning as knob-like projections on the upper part of the trunk, and elongating until maturity. Branching irregular or sub-dichotomous, the ultimate tips being produced after three or four divisions. These tips are generally truncate and cylindrical, bearing a few small cusps, or rarely toothed and flattened, giving a palmate appearance, and are so densely crowded as to obscure the main branches. Large primary branches, if present, are rugose and up to 6 mm. wide, secondary branches 4 mm., tertiary branches and tips about 1.5 mm. wide.

Flesh, soft, white or creamy, opaque, composed of interwoven hyphae. Taste, indistinct and mild. Colour, whitish at base of stem, Deep Dull Lavender in upper parts. In age, the entire plant becomes Vinaceous Drab with the purple colour disappearing (except at the top of the stem) until finally the plant is a smoky greyish green with only a suggestion of purple at the tips, on the main branches, and top of the stem.

Spores, ochraceous in mass, microscopically slightly coloured, elliptical with an obliquely terminal mucro, evenly and finely warted, 4.5–5.8 × 10.3–11.1 μ. Basidia with four straight sterigmata. Habitat—on ground. Localities: Macedon, Eganstown, Mt. Wilson.

The spores of this plant are slightly longer and wider than those of the European specimens, which have spores 3.7–4.4 × 9.8–11 μ, but in other features the plants are similar. *C. fennica* as understood by Bresadola has a purple stem and greenish-yellow branches but it is otherwise similar to the Victorian plant. It is possible that the plants illustrated by Bresadola are over-mature specimens. *C. fennica* has not been previously recorded for Australia but a purple Clavaria, painted by the late Mrs. Ellis Rowan, is probably *C. fennica*. Cleland suggested that the painting might be of *C. vinaceo-cervina* but this species never shows the bright, rich purple or the rather regular branches of the plant illustrated.

C. fennica differs from *C. Nymaniana* in having a thick, glabrous base, deeper colour and roughened, elongated, ochraceous spores. Illustration: Painting by Mrs. Ellis Rowan, Victorian Field Naturalist, Vol. XLIX., No. 2, pl. ii.

CLAVARIA RUFESCENS Fr. ex Schaeff. Schaeff. Fung. Bavar. pl. 288, 1770.

C. holorubella Atk. Ann. Myc. 6: 57, 1908.
C. australiana Clel. Aust. Fung. Notes and Desc. No. 8 Trans. S.A. Roy. Soc., vol. LV. 152-160, 1931.

(Plate XX., fig. 1, pl. XXII., fig. 1, text fig. 1 (F), (K).)

Plants large, 10–12 (sometimes up to 20) cm. high, to 7 (sometimes 10–15) cm. wide. Stem rooting, distinct, stout, smooth, whitish, occasionally with picric yellow stains. A few large branches or many smaller ones arise directly from the trunk, these branching one to four times to form a mass of fine, cylindrical, rather abruptly truncate tips, which bear a few blunt cusps and form a rather loose mass. Axils slightly rounded, branches rugose or occasionally quite smooth. Colour, when young the body of the plant is Cinnamon Buff with the tips Vinaceous. At maturity the purplish colour becomes more pronounced and extensive, and the upper parts of the branches vary between Hydrangea Red and Dark Vinaceous. In age, the entire plant, with the exception of the base, takes on a brownish colour and the purplish colour of the tips is somewhat masked.

Taste, not distinct, mild. Flesh, white and soft, brittle in young plants, soft and somewhat pliable at maturity. Spores, elliptical, with an obliquely terminal mucro, roughened, longitudinally or obliquely striate, ochraceous in the mass. 3–4.5 × 12–15.5 μ. Localities: Cockatoo, Eganstown, Toolangi, Erica, Kallista, Kinglake.

This plant is moderately common in Victoria and can be easily recognized by its vinaceous tips and buffy-brown body. It has been very much confused with *C. botrytis* (for discussion of the differences between the species see under *C. botrytis*). Cleland's description of *C. australiana* only differs from that of *C. rufescens* in the character of the spores, which are described as "microscopically slightly coloured, elongated, oblique, mummy-shaped, not striate, 11–13–16 × 4.5–5.5 μ, rarely 8.5 × 4 μ". I have examined a specimen of *C. australiana* from Cleland's Herbarium and find that the spores are definitely obliquely striate, 10–13 × 4.5–5.5 μ. Thus the plant could be placed as *C. holorubella* Atk., but Coker, on good evidence, regards this as synonymous with *C. rufescens*.

CLAVARIA BOTRYTIS Fr. ex Pers. Pers. Comm., p. 41 (174), 1799. Fr. Hym. Eur. 667.

?*C. acroporphyrea* Schaeff. Fung. Bavar., pl. 176, 1763.
?*C. plebeja* Wulfen in Jacq. Misc. 2: 101, pl. 13, 1781.
C. purpurascens Paulet in Paulet et Lev. Icon. Champ., p. 113, pl. 194, fig. 6, 1855.
C. botrytoides Pk. Bull. N.Y. St. Mus. 94: 21 and 49, pl. 93, figs. 5-7, 1905.
C. conjuncta Pk. Bull. N.Y. St. Mus. 105: 16 and 42, pl. 102, 1906.

(Plate XVIII., figs. 1, 3, pl. XXII., fig. 4, text fig. 1 (P).)

Plants large, branched, up to 16 cm. wide and 12 cm. high. usually medium-sized, up to 8 cm. high, rarely small, 3–5 cm. high. Base solid, tapering, stout, not deeply rooting. Occasionally several plants arise together (pl. xviii., fig. 1), in which case the bases are distinct and relatively slender. Branching irregularly dichotomous, many branches arising directly from the top and sides of the trunk, branches knoblike in youth, at maturity elongated, more or less cylindrical in the upper parts, axils eventually somewhat rounded, with a furrow descending on either side. Tips of branches with a number of obtuse, short tips. At maturity the plant presents a compact cauliflower-like appearance but as the branches continue to elongate, in age the plant is straggling and loose.

Flesh, until maturity, white, solid, crisp, and brittle; in age, soft and lax, somewhat pliable, Pale Buff in colour. Colour of mature plant: base whitish, body of plant, Salmon Buff, tips Grenadine; in youth, the entire plant, with the exception of the white base, is Grenadine, and at maturity this colour is retained by many undeveloped twiglets at the base. In age, the entire plant fades to Salmon Buff or darker but vestiges of the bright pink colour are often apparent at the tips, even in decaying plants.

Spores, Light Buff Yellow, minutely rough to almost smooth, 3.8–4.2 × 7.5–10 μ elliptical, with an oblique, terminal apiculus.

This is an exceedingly common species in Victoria and may be readily identified by the bright pink tips, paler body, and the brightly coloured, undeveloped branches at the base. A pallid, whitish plant, resembling *C. botrytis* in every character except colour, has been collected at Warrandyte on several occasions. In all cases, it has been found growing closely associated with characteristic plants of *C. botrytis* and may be regarded as an abnormal form of it. Cooke records *C. botrytis* (calling it *C. botrytes* in error) for Victoria, Queensland, New South Wales, Western Australia and Tasmania. He places it in the group *Leucosporae* of the sub-genes *Ramaria* but this is incorrect as the spores are coloured. He, also, in common with Cotton and Wakefield and others, has apparently confused *C. botrytis* with *C. rufescens* as he gives the spore measurement as 12–15 × 6 μ. *C. botrytis* and *C. rufescens* can be easily distinguished

as the tips of the former are bright, clear pink becoming paler with age, and are typically thick, while those of *C. rufescens* are usually fine, and are somewhat dusky and Vinaceous Pink in youth, darkening with age. In addition, the spores of *C. rufescens* are obliquely striate and longer than those of *C. botrytis* which are almost evenly roughened. *C. rufescens* has a smooth, tapering base which never shows brightly coloured undeveloped branches.

C. botrytis is edible and quite pleasant to taste. It is apparently eaten by rabbits and possibly other animals; plants gnawed off to ground level and bearing marks of teeth are frequently found. Localities: Common in hilly country south of the Dividing Range. March to November.

Clavaria capitata Lloyd. Myc. Notes, Vol. 7, p. 1107, 1922.

(Plate XVII., figs. 1, 2, 3, 6, pl. XX., fig. 3, text fig. 1 (n).)

Plants branched and bulky, several arising together from a mycelial mass, which binds the soil together. Trunk of plant not obvious as the plants branch close to the base, furrowed, apparently as a result of the fusion of separate stems, white, and frequently with numerous pale, undeveloped branches (or separate young plants) at the base. Primary branches up to 1.5 cm. in diameter, usually about 0.8 cm.; secondary branches arising in a group from the primary branches, upright and rather crowded, axils very acute, but the branches often bend sharply outwards before continuing their upward growth. The secondary branches may give rise to another series in a similar manner or may produce the ultimate tips. These at first consist of a number of sub-globose, non-viscid swellings at the end of each branch and soon after their formation, differ sharply in colour and texture from the body of the plant. Towards maturity, these tips expand laterally and often coalesce; thus the upper surface of the plant may become more or less continuous and is usually finely convoluted. When the tips are not at approximately the same level, smaller areas become continuous and the plant presents a terraced appearance. The increase in size of the tips tends to strain the lower parts of the plant and splitting frequently occurs at the axils. At maturity, the tips are extremely sticky to the touch but the rest of the plant is dry. Colour, body of plant Maize Yellow to Pale Orange Yellow. Tips paler than Honey Yellow but yellower than Chamois, semitranslucent. Flesh white, crisp and brittle, taste mild.

Spores 11–13 × 4.2–5 μ. Elliptical, with a prominent oblique apiculus, definitely rough, ochraceous in mass, microscopically hyaline. Basidia most frequently with two, sometimes with four, sterigmata, hymenium covering the branches as well as the tips, clamp connections not seen.

The hyphae composing the body of the plant are only slightly interwoven and rather broad. In the young state the hyphae composing the tips are closely compacted and as the plant matures they proliferate and become much finer, intertwining freely. It is at this stage that fusion between closely approximated tips occurs and this accounts for the fact that small, closed pockets, lined with fertile hymenium, may often be observed in prepared sections of the tip region. The growth at the tips is not so much in a vertical direction as lateral, and results in the curling back of free edges of the tips. Finally, these tips develop normal basidia but this occurs later than on the branches (this may account for Lloyd's statement that the branches are sterile). The stickiness of the tips may be due to the exosmosis of sugary substances as sections of mature tips show no breakdown of the hyphae composing them. It has been observed that the hyphae of the tips, both before and after the production of basidia and spores, are much more densely protoplasmic than those immediately beneath the hymenium on the branches, and than those composing the main substances of the plant.

This plant, as far as is known, is peculiar to Australia. It was first collected by Mr. E. J. Semmens, of the Creswick Forestry School, and was sent to Lloyd, who published the following description.

"*Clavaria capitata*—stems slightly sulcate, few branched. Branches terminating in sub-globose heads bearing the hymenium, spores 7–13–16 μ, if coloured, very pale, smooth, laterally apiculate at the base. Evidently grows on the ground. Colour, which Mr. Semmens says has not changed much, is the Isabelline colour that most white plants take on in drying, nothing distinctive. The idea of a Clavaria not having the hymenium over stems or branches, but confined to terminal heads, is a new one, I think, in Clavarias, hence could be made a new genus (*Capitoclavaria capitata*)."

Although Lloyd does not make it clear that he was describing a new species, no trace of an earlier description of a plant bearing this name can be found. In a letter, Mr. Semmens says that Mr. Lloyd did not mention at the time that it was a new species, but he, himself, had always understood it to be so. The identification of *Clavaria capitata* from Lloyd's description would be a difficult matter, but Mr. Semmens has given us a co-type specimen and this is identical with the plants I have described above. As the co-type (and further collections of the plant) show differences from Lloyd's description, the following amended description is put forward.

CLAVARIA CAPITATA Lloyd em. Fawcett.

Plantae ramosae et satis magnae, gregariae, emergentes in fascibus e massa mycelii humum colligantis. Trunca non manifesta, juxta terram se dividens, axiles acuti. Cacumina

primum sub-globosa, non-viscida, diende se dilatantia, interdum conjungentia in massam densam, nunc viscida et maxime differentia textura et colore ab ramis qui leves et non-viscidi sunt. Color cacuminum inter "Honey Yellow" et "Chamois," reliquarum partium praeter basis qui albus est "Maize Yellow" ad "Pale Orange Yellow." Caro alba, crispus et fragilis, sapor blandus.

Hymenium et ramos et cacumina tegit; postea in cacuminibus oritur. Basidia plurimum bispora, interdum quadrispora. Sporae 11–13 × 4.2–5 μ, *ellipsoideae cum apiculo obliquo prominenti, omnino asperae, ochraceae. Loc. Ararat (type). Kinglake, Tourrorrong, Healesville, Cockatoo.*

Clavaria capitata is a very well marked species and may be distinguished from all others by its pale yellow body and sharply contrasting sub-globose or expanded tips. *Clavaria ochraceo-salmonicolor* approaches rather close to this species in the possession of a number of sub-globose swellings at the tips but these do not differ in colour or texture from the rest of the plant.

Clavaria sanguinea Fr. ex Pers. Pers. Obs. Myc. 2: 61, pl. 3, fig. 5, 1799.

(Plate XXI., fig. 10, text fig. 1 (h).)

Plants stout and branched, up to 7 cm. high and 3–6 cm. broad. Branches arising from a short, stout stem which is pointed at the base and not deeply rooting. Main branches stout, arising near the ground level and continuing to the base as furrows. Many branches dividing irregularly to form very many small ones which branch once or twice again to form the ultimate tips which are blunt and with one or two blunt cusps. Colour, when young, pallid yellow, later deepening to Maize Yellow, base persistently whitish. Base and all other parts staining a deep reddish brown when handled. Flesh white, soft, only superficially staining red. Taste and odour, very faint. Spores ochraceous, slightly rough, elliptical, 9–11 × 3–4.5 μ with several small guttae and an obliquely terminal mucro. Growing on ground—Kinglake. Not previously recorded for Australia.

This is a distinct and well-marked species but there is some doubt as to its correct name. While otherwise similar to the plant Coker interprets as *C. sanguinea,* our plant has larger spores. Maire and Bresadola, among others, interpret plants which closely resemble ours in spore character, habit, and colour as *C. flava.* However, *C. flava,* as now understood, does not stain red on bruising, and in view of the fact that in all other characters, except size of spores, our plants and Coker's are similar, it seems best to disregard the discrepancy in spore size and call our plant *C. sanguinea.*

Clavaria Spores.

Spores of the following species:—(A) *C. aurantia;* (B) *C. corallino-rosacea,* (C) *C. sinapicolor;* (D) *C. acuta;* (E) *C. vermicularis;* (F) *C. rufescens;* (G) *C. pulchra;* (H) *C. sanguinea;* (J) *C. Miyabeana;* (K) *C. australiana* (co-type); (L) *C. fusiformis;* (M) *C. fennica;* (N) *C. capitata* (co-type material); (O) *C. luteostirpata* (type); (P) *C. botrytis;* (Q) *C. pallidorosea* (type); (R) *C caepicolorosa* (type). Magnification 1125.

Explanation of Plates.

Unless otherwise stated, all photographs are natural size.

PLATE XVII.

FIG. 1.—*Clavaria capitata*, young plant showing unexpanded tips.

FIG. 2.—*C. capitata*, mature plant with expanded tips.

FIG. 3.—Vertical section of the end of a branch of a mature plant of *C. capitata*. Notice the recurved margins, fusion of adjoining tips, and totally enclosed pockets lined with the hymenium. The white lines represent the hymenium. Magnification 6 ×.

FIGS. 4 and 5.—*C. fusiformis*.

FIG. 6.—*C. capitata*. Aspect of young plant looked at from above.

PLATE XVIII.

FIG. 1.—*C. botrytis*, showing clustered habit, and undeveloped basal twiglets.

FIG. 2.—*C. fennica*. Portion of young plant. Notice knob-like rudiments of the branches.

FIG. 3.—Large plant of *C. botrytis*, showing elongated branches characteristic of mature and over-mature plants. Two-thirds natural size.

PLATE XIX.

FIG. 1.—*C. pulchra*.

FIG. 2.—*C. caepicolerosa*. Mature plants. Notice well-defined stem.

FIGS. 3 and 4.—Young plants of *C. caepicolorosa*.

FIG. 5.—*C. luteostirpata*.

PLATE XX.

FIG. 1.—*C. rufescens*. One-half natural size.

FIG. 2.—*C. pallidorosea*.

FIG. 3.—Enlarged view of the tips of young plant of *C. capitata*. Notice the sharp difference in colour of the tips and the branches.

PLATE XXI.

FIG. 1.—*C. sinapicolor*. Typical large plant.

FIGS. 2, 3, 4, 5, 6, 7.—Small plants of *C. sinapicolor*, showing varying degrees of fusion.

FIG. 8.—Medium-sized plant of *C. sinapicolor* apparently derived from a large number of smaller ones.

FIG. 9.—Medium-sized single plants of *C. sinapicolor*.

FIG. 10.—*C. sanguinea*.

PLATE XXII.

FIG. 1.—*C. rufescens*, young plant.

FIG. 2.—*C. corallino-rosacea*.

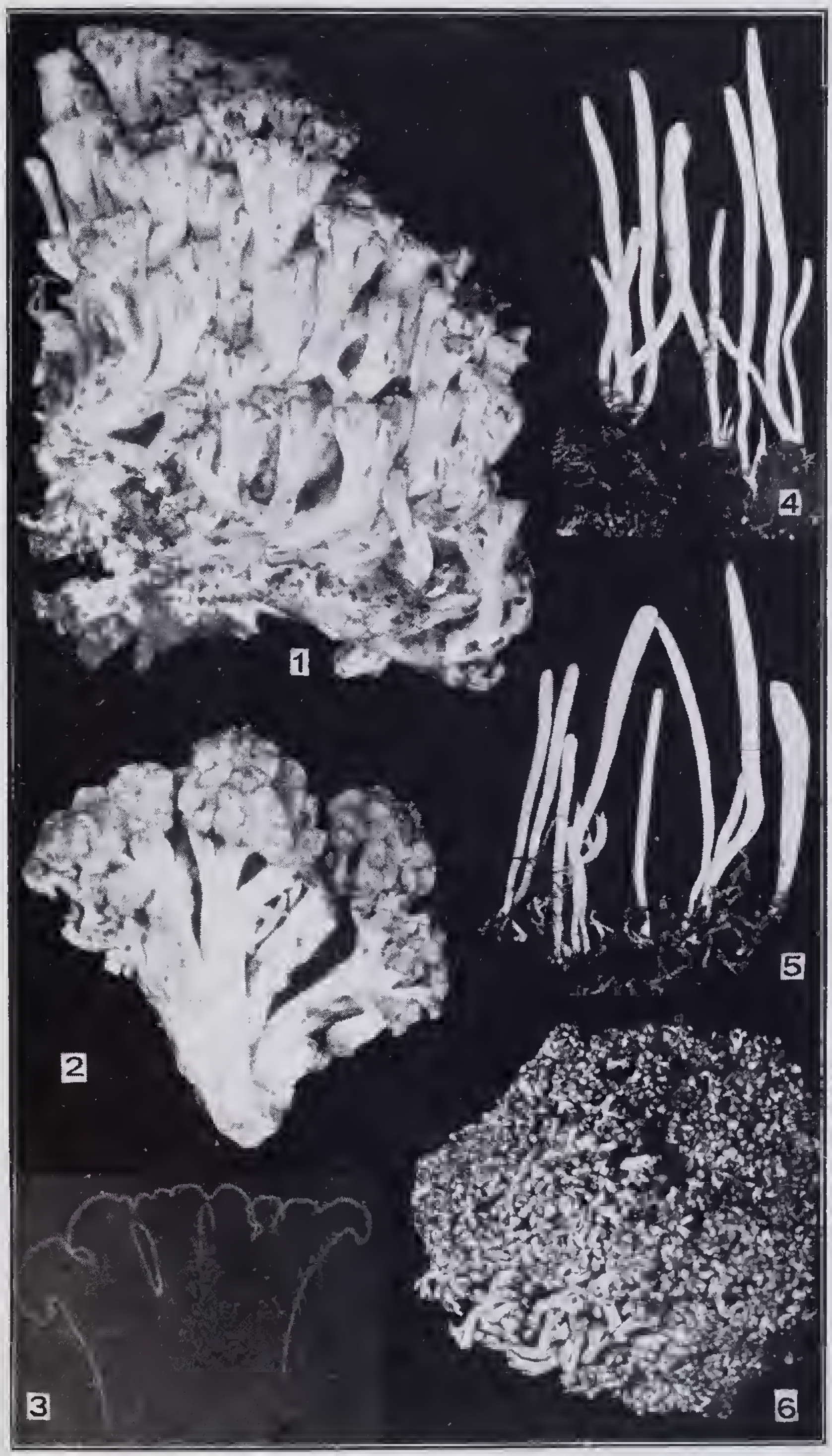
FIG. 3.—*C. aurantia*.

FIG. 4.—Young plant of *C. botrytis*. Notice the extremely stout base.

FIGS. 5 and 6.—*C. corallino-rosacea*, showing characteristically twisted plants.

PLATE XXIII.

C. Miyabeana.



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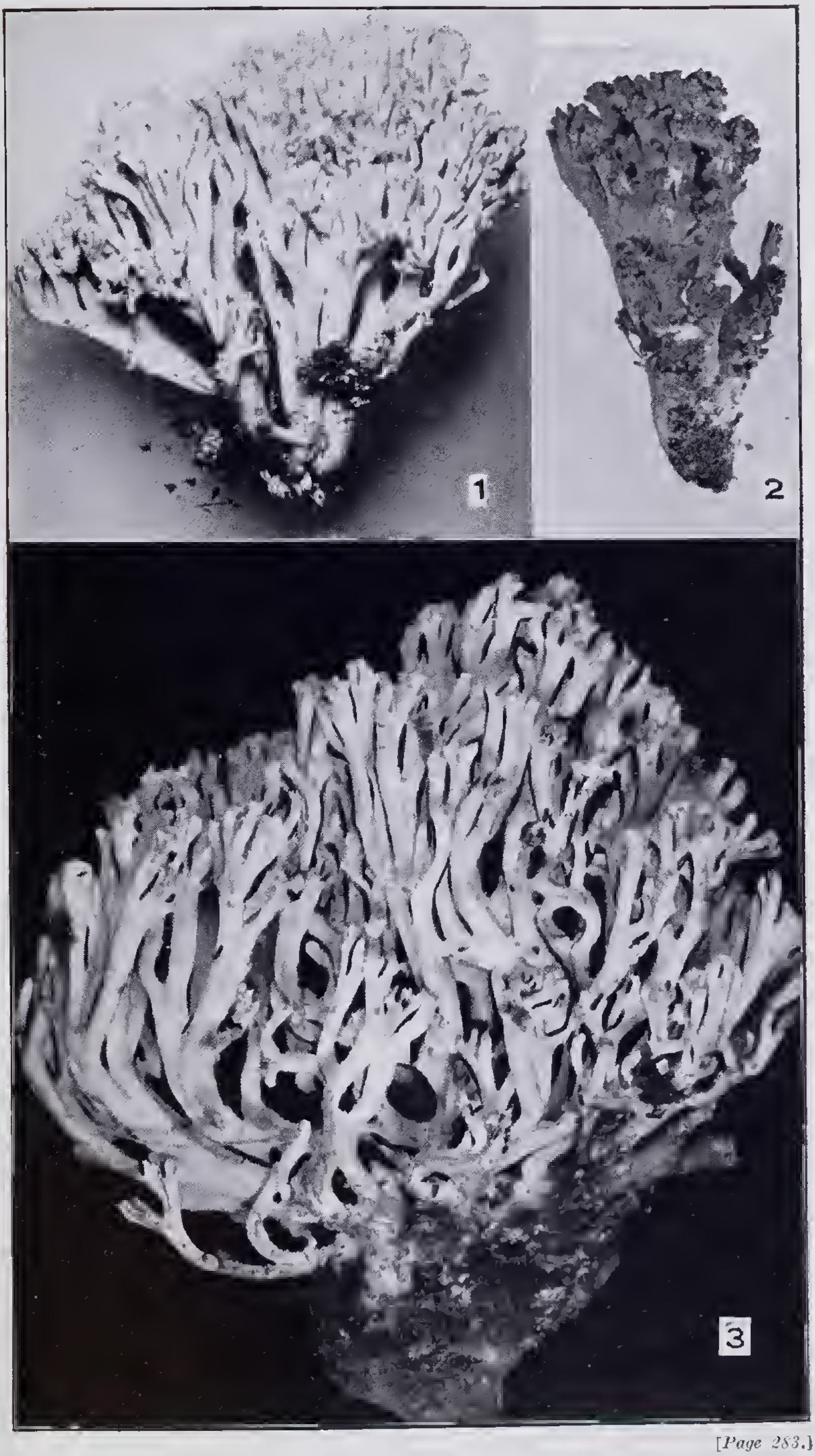
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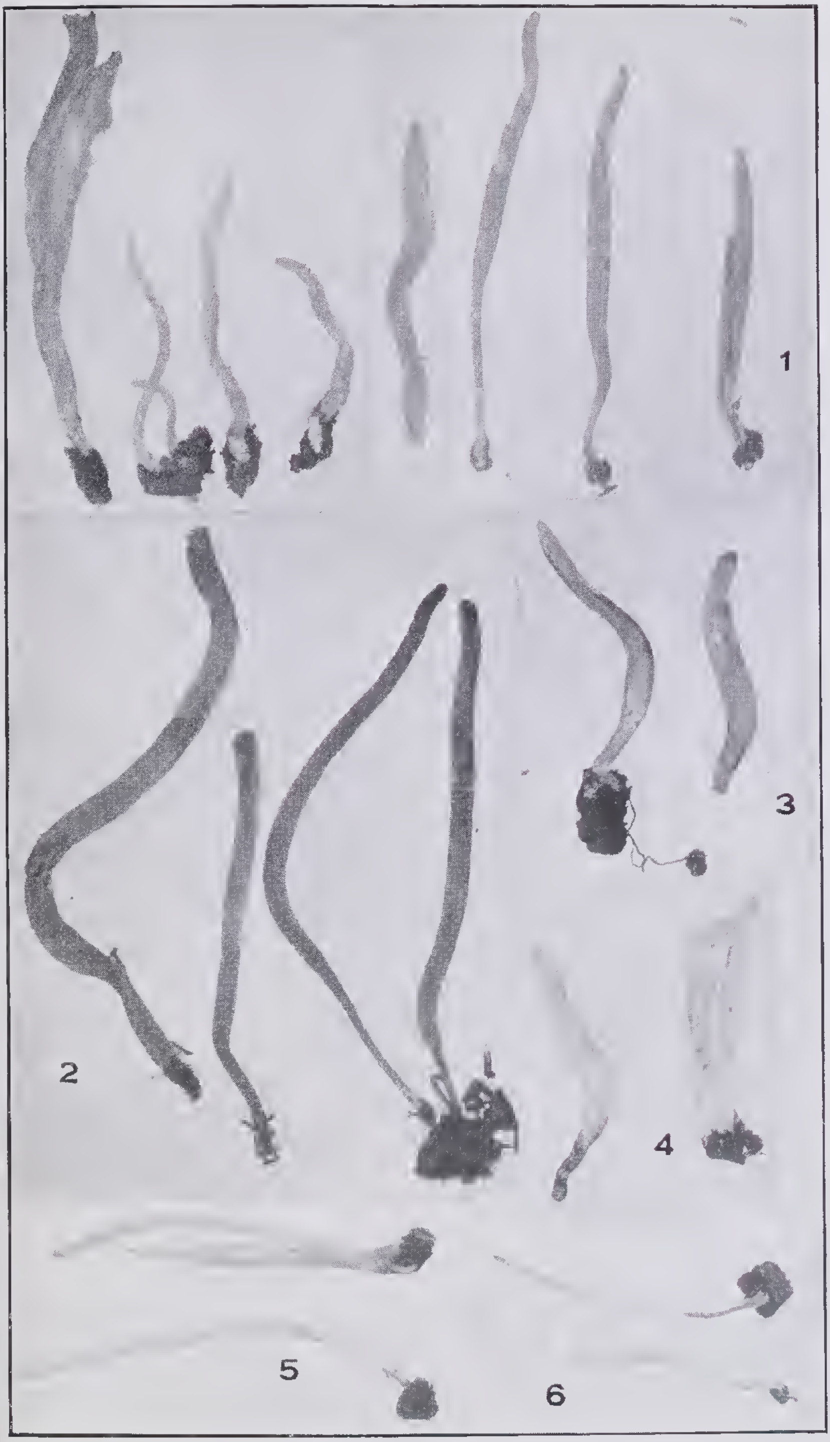
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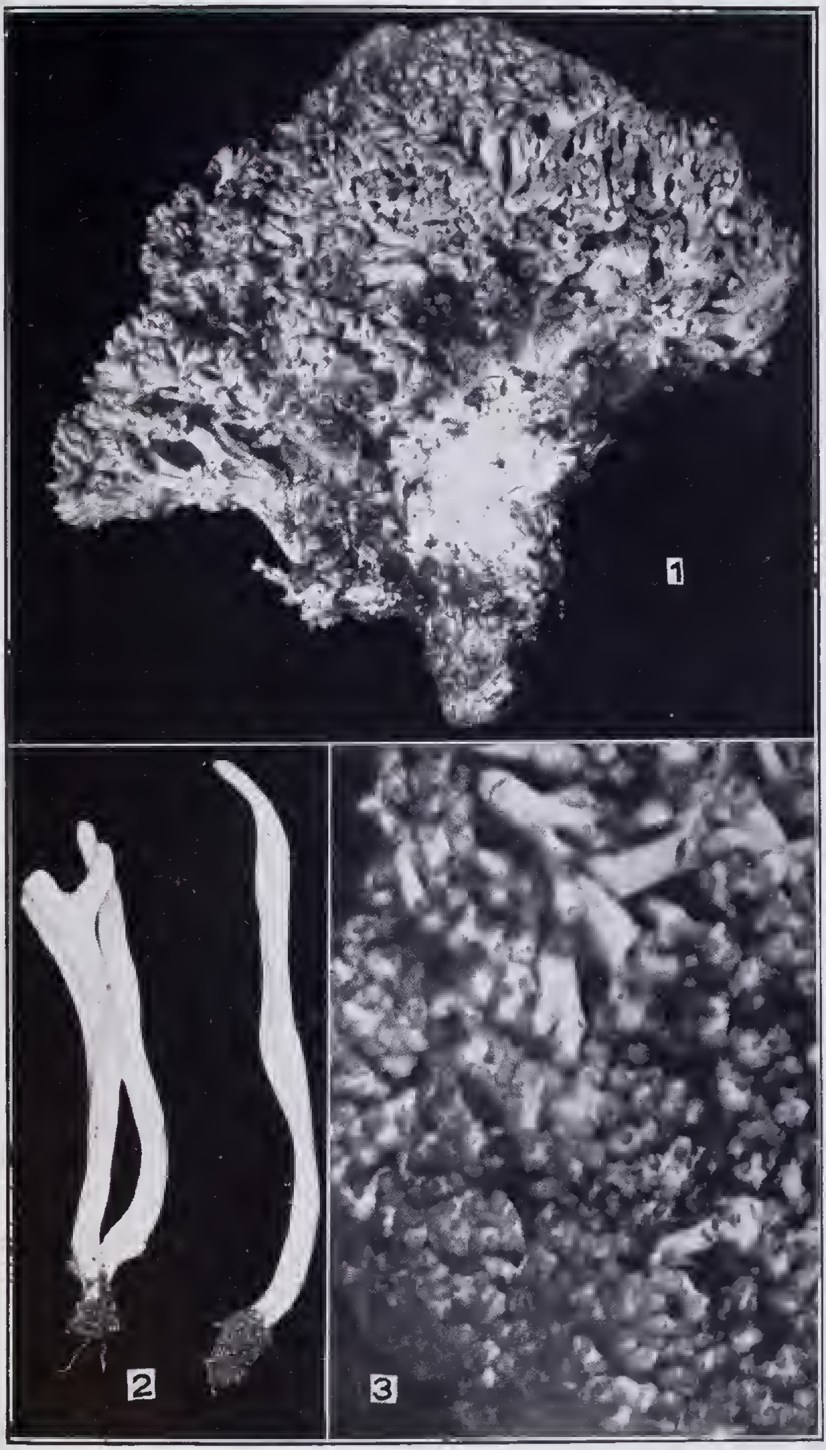
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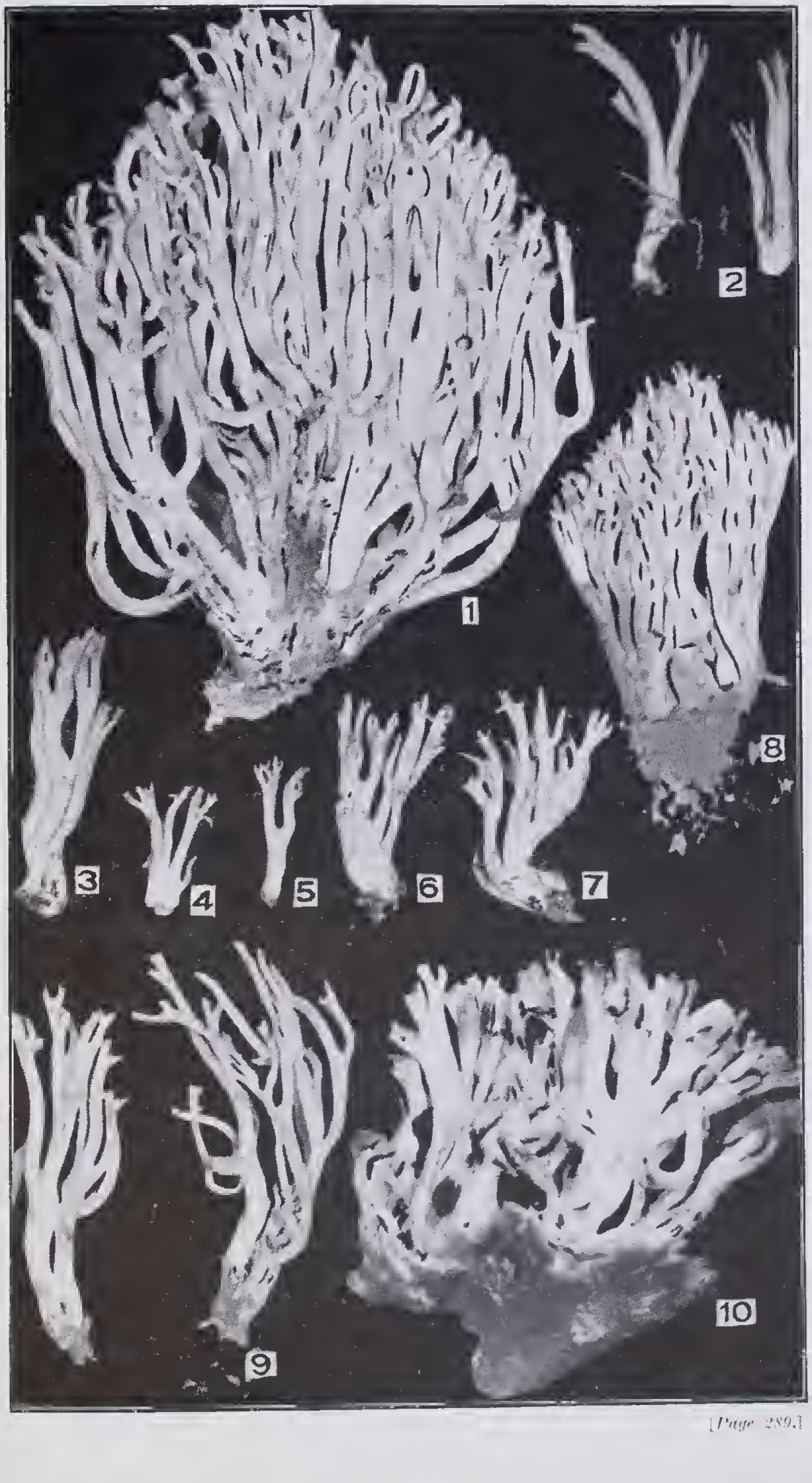
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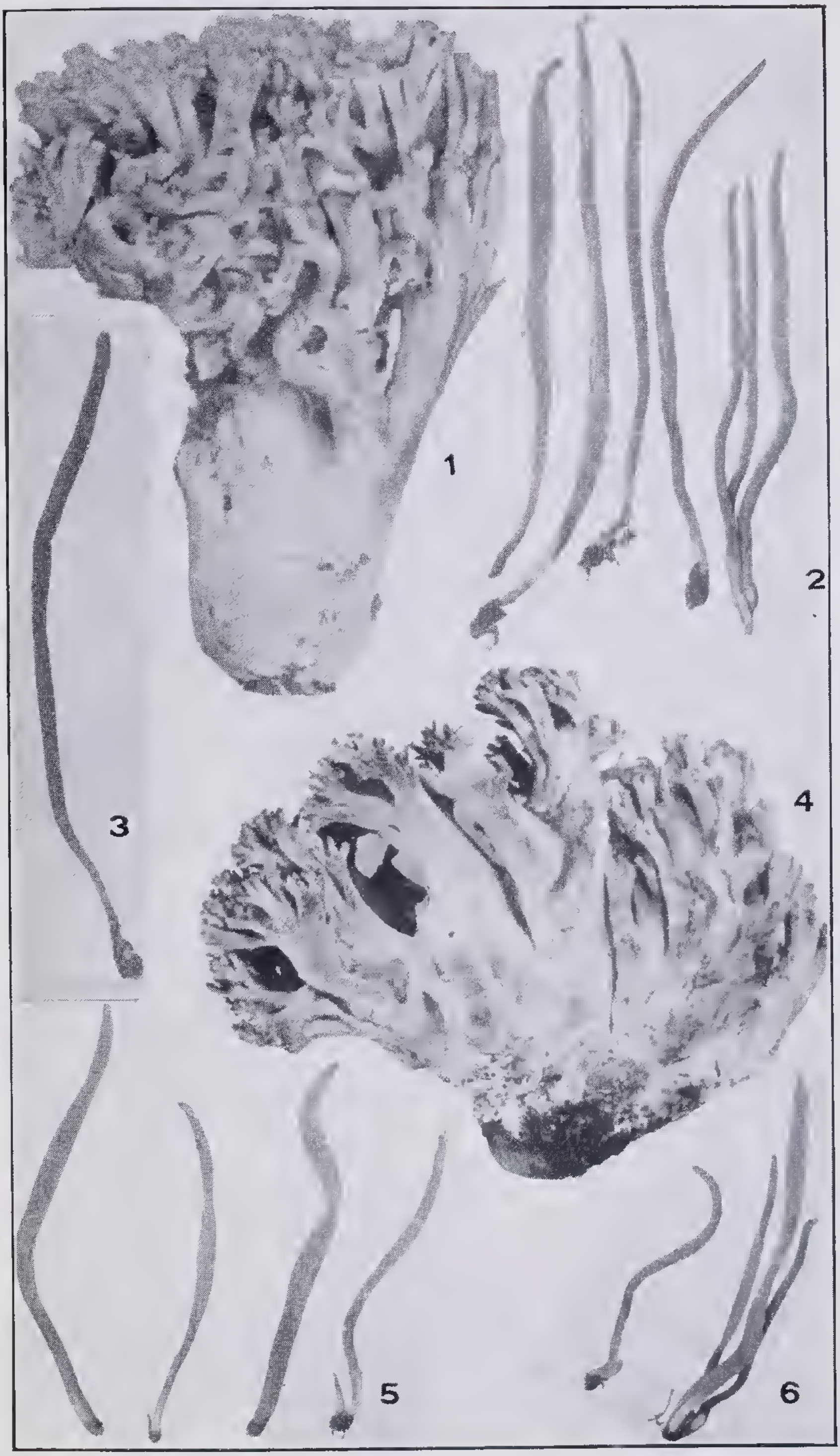
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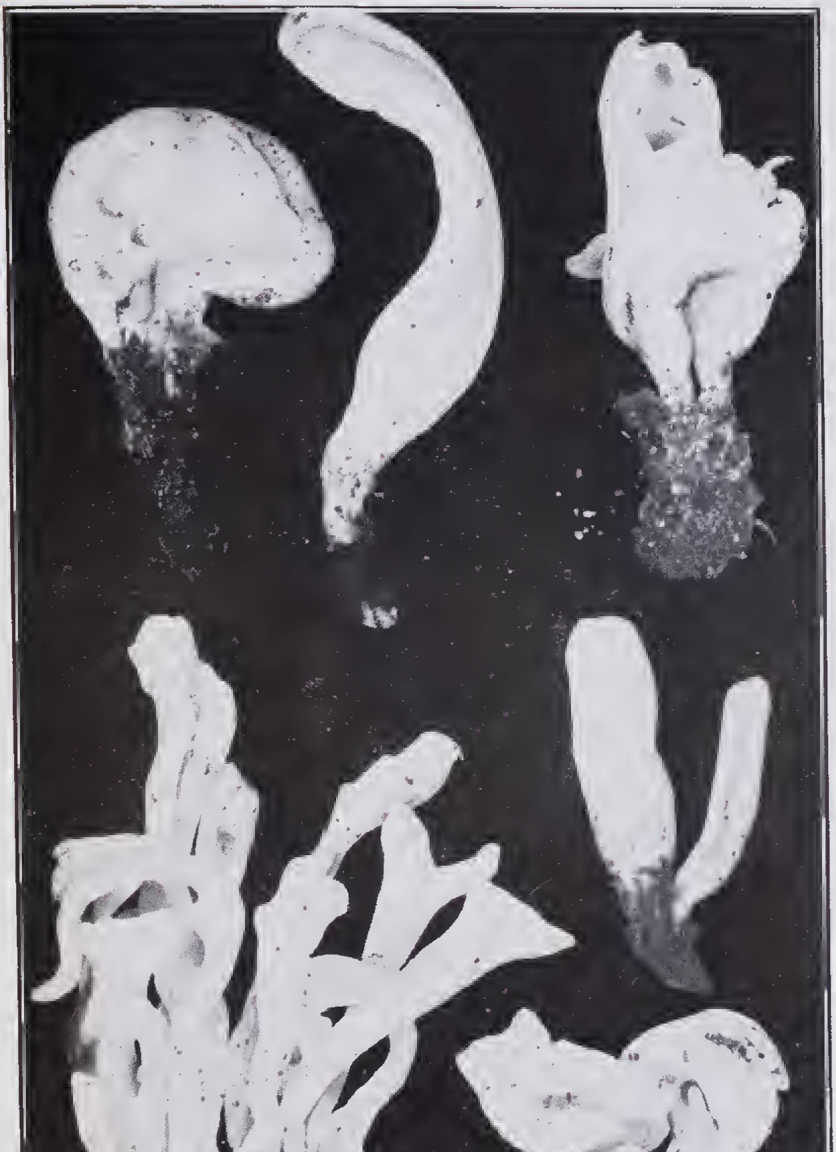


TOPOGRAPHIC MAP OF
NORTH WESTERN VICTORIA
NEW
SOUTH
WALES
Murray River
MILDURA
L. Walla Walla
MORKALLA
NOWINGI
Raak Plain
Hattah Lakes
ROBINVALE
YUNGERA
MILLEWA
.MILLEWA SOUTH BORE
137. ROCK HOLES BORE
175. BELL BIRD BORE
155. CLIFFS BORE
Pink Lakes
TIEGA
OUYEN
KULWIN
MANANGATANG
KARKAROOC
MURRAYVILLE
SWAN HILL
TATCHERA
LAKE TYRRELL
ULTIMA
SEA LAKE
THE BIG "DESERT"
Pine Plains
BIG BILLY BORE
WEEAH
199 MILMED BORE
LASCELLES
231 LILY SWAMP BORE
LAKE ALBACUTYA
HOPETOUN
Lalbert Creek
THE BIG "DESERT"
286 CHINAMANS FLAT BORE
Outlet Creek
Tyrrell Creek
AVOCA RIVER
LODDON RIVER
BIRCHIP
GREDGWIN
327 TULLYVEA BORE
LAKE HINDMARSH
NETHERBY BORE
WYCHEPROOF
KARA KARA
YANAC
GLADSTONE
BORUNG
Yarriambiac Creek
L. Buloke
SERVICETON
NHILL
DONALD
KORONG VALE
Lawloit Range
DIMBOOLA
WEDDERBURNE
Mt. Korong
LOWAN
Dunmunkle Creek
AVON RIVER
THE LITTLE "DESERT"
MURTOA
ST. ARNAUD
INGLEWOOD
HORSHAM
WIMMERA RIVER
CARPOLAC
BOLANGUM
GLENORCHY
The Grampians
The Black Range
BRIM SPRINGS
STAWELL
EDENHOPE
Mt. William Creek
BALMORAL
GLENELG RIVER
DUNDAS
ARARAT
Boundary of South Australia
LEGEND
CONTOURS 200
COUNTY BOUNDARIES
RAILWAYS Station
BOUNDARY OF MALLEE Mallee
LAKES
SWAMPS
BEDROCK OUTCROPS
SCALE
0 2 4 8 16 24 Miles
Edwin S Hills
1938

[Proc. Roy. Soc. Victoria, **51** (N.S.), Pt. II., 1939.]

Art. XIII.—*The Physiography of North-Western Victoria.*

By EDWIN SHERBON HILLS, Ph.D., D.Sc.

[Read 8th December, 1938; issued separately, 24th July, 1939.]

Introduction.

In that portion of the Murray Basin Plains which lies within Victoria, two major physiographic divisions may be recognized, the boundary between them being the Loddon River or, more precisely, the western edge of the Loddon flood plain. The Loddon and the streams to the east of it that cross the plains of the Northern District join the Murray, but west of the Loddon streams from the Highlands fail to reach the Murray and usually terminate in shallow lakes. Thus, between the terminations of these streams and the Murray there is an area from which flowing streams are absent. It is the western section of the Murray Basin Plains, from the Loddon River to the boundary of South Australia, and from the edge of the Western Highlands to the Murray River, that forms the subject of this paper. Within the area dealt with are included the Victorian Mallee, the Wimmera country, and portion of the Murray Valley.

It gives me very great pleasure to acknowledge the help I have received during the preparation of this paper, from officers of the State Rivers and Water Supply Commission, the Geological Survey, the Railways Department, the Forestry Commission, the Lands Department, and the Country Roads Board. For information concerning the Mallee, I am especially indebted to Mr. R. F. McNab, Divisional Engineer of Water Supply for the Mallee and Wimmera, whose co-operation was essential for the preparation of the topographic map (fig. 1). I am also indebted to Mr. W. Baragwanath, Director of the Geological Survey of Victoria, for the permission to use information in an unpublished Bulletin on copi deposits by Mr. S. B. Abbot, for facilities placed at my disposal in the Mines Department, and much help in other ways. Mr. A. S. Kenyon has also very kindly discussed many problems with me, and allowed me to draw freely on his unique knowledge of the Mallee. To Mr. P. Cresswell, Secretary of the Shire of Lowan, I am obliged for information concerning bores and wells near Nhill, and to Mr. W. J. Zimmer, chief forester for the Mildura district, for help in the delimitation of the Murray Valley in the far north-west.

Topography.

A topographic map of the area under consideration, showing contours at 50-ft. intervals, is given as fig. 1. This map was construeted from all available sources of information, but is largely based on data supplied by the State Rivers and Water Supply Commission and the Geological Survey, and on trial railway surveys. In Co. Lowan data were also obtained by aneroid.

The most obvious feature brought out by the map, and one that differentiates the area from the plains east of the Loddon, is the existence of well-marked ridges and troughs whose trend varies from north-west to east of north. East of the Loddon, on the other hand, the main contour lines run east-west, and there are extensive tracts of country which are almost perfect plains, sloping at a rate of 5 feet in 1–2 miles towards the Murray. The existence of relatively strong topographic features west of the Loddon has important consequences in regard to the lay-out of irrigation channels, and some of the main ridges are already distinguished by name by the officers of the Water Supply Commission (see fig. 2). The easternmost ridge is that on which Cannie township is situated, and is known as the Cannie Ridge. South-east of this ridge is an area of high land around Gredgwin. The next ridge to the west runs north-south through Robinvale and Annuello, and continues southwards, with a break east of Kulwin, along the western side of Lake Tyrrell. It is known as the Tyrrell Ridge. Further to the west is a series of ridges and troughs which is best exhibited in the southern portion of Co. Karkarooc, but which continues north-westerly, with one intervening strip of low land, and develops into a well defined ridge at Walpeup (350 feet). There the ridge is referred to as the Walpeup Ridge, and its southerly continuation is known as the Denying Ridge. It is broken in the north by an extensive low area, but on the same line is a very well marked ridge in Co. Millewa, trending north-west and extending into South Australia. This may be termed the Millewa Ridge. Extending south from Mildura to beyond Red Cliffs is a minor ridge which is economically important in that it cannot receive water by gravitation from the main Mallee water channels, and necessitates pumping from the Murray. This may be termed the Red Cliffs Ridge. In Co. Lowan, the ridges trend N.N.W.–S.S.E., but, although very well marked in the field, they are not comparable in size with the main ridges above referred to, and are probably also of different origin. d'Alton (1913) has named the most prominent of these Lowan ridges, which rises to 650 feet above sea level between Diapur and Miram, the Lawloit Range.

In contrast with the ridges there are certain broad topographic basins, and also extensive flood plains formed by the larger streams. One of the largest basins is that in which the Lake

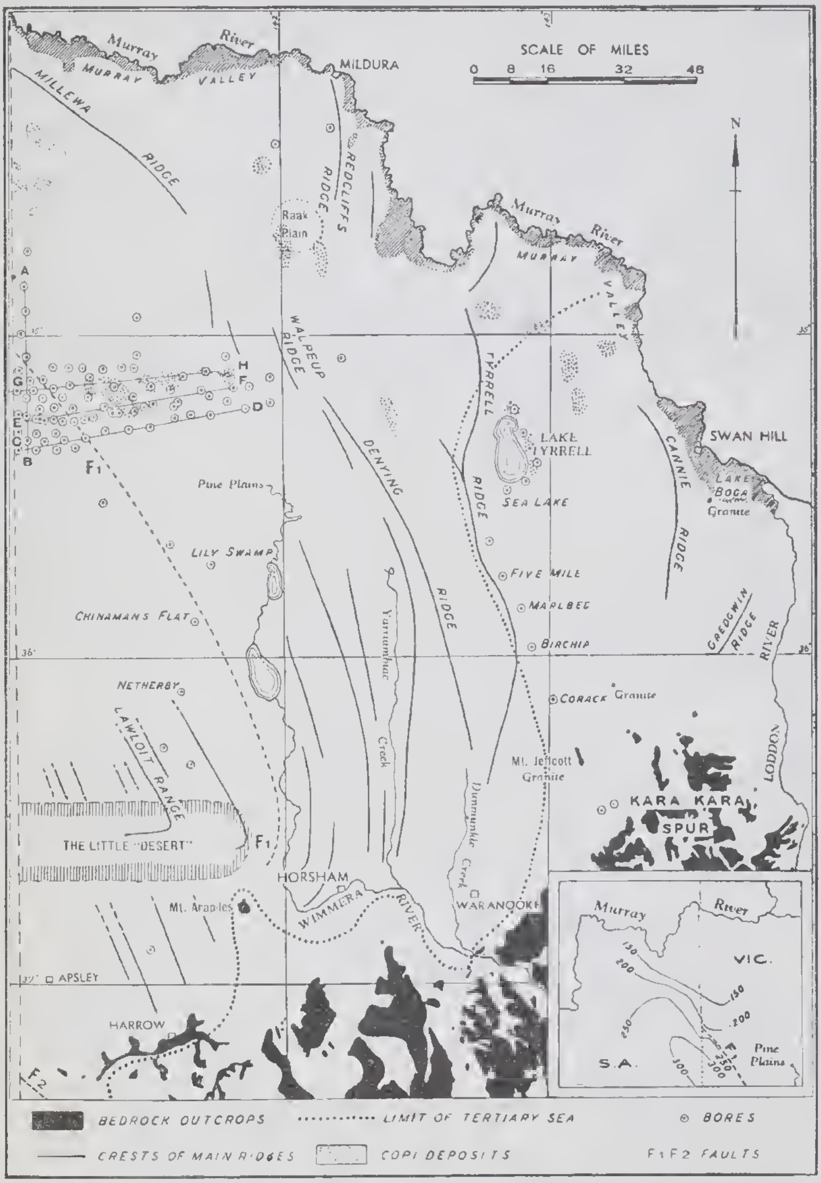

Fig. 2.—Map showing the chief structural features of North-Western Victoria. (NOTE.—For Kara Kara Spur read Gladstone Spur.)

Tyrrell–Lake Wahpool group of lakes is situated. It may be termed the Tyrrell Basin. This basin is bounded on the east by the northerly continuation of the Cannie Ridge, which swings round the northern edge of the basin to join the Tyrrell Ridge. The latter forms the western edge of the basin. Another important area of low land is that which separates the Walpeup Ridge from the Millewa Ridge. Within it lies the Raak Plain and an extensive system of shallow salt lakes in the northern part of Co. Karkarooc. This low area may be termed the Raak Basin. The boundary of South Australia crosses two other basins, near Cow Camp and Cudmore's Tank respectively, in Co. Millewa.

All the above-mentioned ridges and basins are of large dimensions, and are entirely distinct in origin from the small ridges and intervening troughs resulting from aeolian sand drift. The sand ridges have a general trend slightly north of east and south of west, and rarely rise as much as 50 feet above the general level of the country (see fig. 7). As well as the east-west sand ridges there are, on the eastern sides of nearly all the small lakes and on many of the swamps, crescentic ridges of sand or loam. The latter may be seen to perfection around the lakes between Kerang and Swan Hill, and they appear to be unique land forms, as I can find no reference to the occurrence of similar features in other parts of the world. They were commented upon first by Major Mitchell, who was so struck with their peculiarities that he devoted many pages to their description (Mitchell, 1839).

General Geology.

The area constitutes portion of the ancient Murray Gulf (Gregory, 1903). Such bores as have been carried down to bedrock have bottomed on various rock types, as follows (see Jack, Stirling, and Checchi, 1897; for location of bores see figs. 1 and 2, and Kenyon, 1914):—

Netherby: Sandstones, shales, and conglomerates at 978-2,175 feet; porphyry between 2,175 feet and 2,200 feet.
Chinaman's Flat: Clay shale, probably bedrock at 1,473 feet.
Lily Swamp: Green shale taken as bedrock, at 1,080 feet.
Corack: ? Silurian at 270 feet.
Birchip: Metamorphic rock at 760 feet.
Marlbed: "Blue" rock, 863-899 feet, then granite or micaceous sandstone.
Five Mile: Quartz, clay shales, etc., at 810 feet.
Sea Lake: Kaolin, quartz, etc., at 828-1,076 feet, then shale with quartz.
Lake Boga: Granite at 200 feet.

The records of metamorphic rocks at Birchip and quartz veins at Sea Lake, with possible granite at Marlbed, show that, in the series of bores running north from Birchip, the bedrock is probably similar to the exposed Palaeozoic rocks on the northern edge of the Western Highlands, where metamorphic

rocks, granites, and reef quartz occur. The prevalence of granitic monadnocks in the area between Lake Boga, Wycheproof, and Wooroonook, and at Mt. Hope and Pyramid Hill to the east, suggests that much of the eastern part of the district is probably underlain by this rock.

Marine Tertiary rocks are restricted to the western portion of the area (see fig. 2). East of the marine incursion the bedrock basin was filled mainly with a continental series of ligneous clays, fluviatile and lacustrine sands, gravels, and gypsum, with possibly some estuarine deposits. In the area where marine deposits occur, ligneous clays of continental and shallow marine origin are overlain by Miocene limestones, and these in turn by marine Pliocene shell marls and glauconitic sands, and by later deposits. According to Chapman (1916), marine strata of Upper and Lower Pleistocene age occur in some of the bores in the northern parts of Co. Weeah. The Pleistocene and Recent deposits are, however, dominantly lacustrine, fluviatile, and aeolian in origin.

The Origin of the Major Topographic Features.

The Ridges and Dry Valleys of County Lowan.

Two previous authors (Dennant, 1886; Fenner, 1918) have referred to the origin of these features. Dennant, noting the universal sandy nature of the soils on the ridges, the presence of sandstones at "Mortat" (now Goroke) and Kadnook, and the fact that the strike of the ridges is parallel to that of the chief sandstone ranges in the Grampians, considered them to represent Grampians sandstones partially buried by Tertiary deposits. Fenner, in discussing the physiography of the Glenelg, concluded that the valleys, many of which are occupied by lines of swamps, represent old river courses. These two interpretations are not incompatible, and Dennant has also remarked that the lines of swamps probably represent old stream courses, desiccated by climatic changes. He remarks that, after heavy rain, Lake Wallace drains to the Booroopki Swamp, 26 miles to the north, by means of an actual current.

Concerning the ridges, it is true that relatively hard sandstones underlie the surface sand in all of them that I have examined. These sandstones are red or mottled, and in places develop a very hard ironstone capping. They occur in sandy patches near Nhill, where they are extensively quarried for use as a road metal, in the Lawloit Range, where they outcrop at the surface, in the Little "Desert," at Goroke, and at Kadnook, and there can be little doubt that the majority, if not all, of the ridges with poor sandy soils that occur in Co. Lowan are composed of this rock. The presence of these sandstones in the Little "Desert" explains in part the existence of this feature, although, from aneroid levels, it would appear that the "Desert," near its

western end, is not a well marked ridge. However, d'Alton (1913), who traversed the eastern part of the "Desert," shows a sandstone ridge running east-west through it, and terminating east of the Kaniva-Goroke road. This indicates that the origin of the "Desert" is essentially similar to that of the sandy N.N.W. trending ridges, its existence being determined by the nature of the soils derived from the sandstones which occur in it.

Petrologically, the dominantly red sandstones of which the ridges are composed are quite unlike the typical Grampians sandstones, especially in their high iron content and the lack of a siliceous cement. Furthermore, wherever the bedding could be observed, the sandstones of the Lowan ridges are flat-lying, whereas the majority of the Grampians beds are dipping at high angles. It is much more probable that the sandstones are Tertiary in age.

Late Cainozoic Warping in County Dundas and County Lowan.

As pointed out by Fenner, a divide was formed in late Cainozoic times by warping about an east-west axis running through the highlands of Co. Dundas. At the present time the northern part of this county, which is drained by tributaries to the Glenelg and the Wannon, affords an excellent example of a warped plain, dissected to the stage of late youth. Between the streams, remnants of the plain are preserved in many places, and a north-south traverse shows clearly, by the alignment of the summits of these remnants, both the northerly and the southerly or south-westerly slopes, on either side of the warp axis (Pl. xxiv., fig. 1). This warped and dissected plain consists of Cainozoic sandstones, sands, quartz gravels, and ironstone gravels, overlying Jurassic sandstones, granites, Cainozoic lavas, and other rocks. The ages of the Cainozoic rocks are uncertain. At Harrow, fossils indicate the presence of Miocene beds, but it is probable that the surface of the plain was developed long after this date, for the ironstone gravels have the appearance of buckshot gravel; they are very widely distributed, and may represent a fossil soil horizon. Support for this is also given by the fact that dips observed in Cainozoic sands between Casterton and the Hummocks show that the surface of the dissected plain is not parallel to the dip in these sands, whereas the ironstone gravels, where observed by me, are parallel to the surface of the old plain and give rise to the steep escarpments that occur around the remnants of it. Furthermore, the presence of the Murray River tortoise *Eurydura macquariae* (Gray), at Carapook (Chapman, 1919), indicates that at some recent date communication by a dominantly fresh-water route was possible between the northern and southern streams. The suggestion is that the ironstone cappings on the Dundas Highlands were developed as soil horizons or as deposits in swamps or lakes during late Cainozoic times, and that the uplift of these Highlands is therefore of fairly recent date.

The slope of the warped plain from the axis in Co. Dundas continues north across the Gleenlg into Co. Lowan, and there can be little doubt that before the dissection south of the Glenelg was carried very far, north-flowing streams ran into Co. Lowan. These streams dissected the Tertiary cover of the plain, and cut well-defined valleys which were later abandoned. The causes of this abandonment will be discussed later (p. 308). This suggestion affords an explanation of the existence of the dry valleys running north from Fulham and from the White Lakes F and W, fig. 1), but there are difficulties in applying it to the ridges and valleys further west near Edenhope, and those north of the Little " Desert " between Kaniva and Serviceton. These features are remarkably straight and parallel, and they are not continuous from north to south but are broken by the Little " Desert " and by other sandy patches of high ground (see figs. 1 and 2).

In elucidating the origin of these ridges and valleys, it is important to know whether the red sandstone of the ridges occurs beneath the heavy soils and clays of the valleys, or whether the valleys have been cut through a formerly continuous sandstone capping, leaving the ridges as remnants. Wells and bores, after passing through the superficial soils, come first upon loam and clay, then 10 to 30 feet of red sandstone, hard in places, and then enter marine limestones probably of Miocene or Lower Pliocene age. It appears, therefore, that as is suggested by the discontinuity of the valleys, the ridges represent open anticlines in which the red sandstones are brought to the surface, and that in the intervening synclines the overlying clays are preserved (see fig. 3). The water table developed above these clays intersects the ground surface in winter, causing the swamps, which dry up in summer as the water table is lowered owing to the low rainfall and high evaporation.

It appears to me to be improbable that these folds should be due to lateral compression acting on the Cainozoic rocks, for these are less than 1,000 feet thick in Co. Lowan, and no

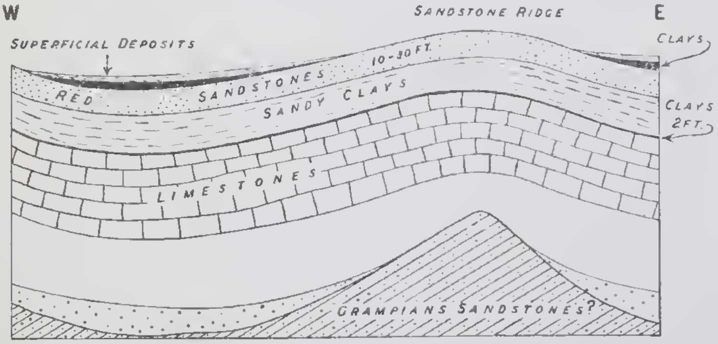

Fig. 3.—Cross-section showing the probable geological structure in Co. Lowan. Approximate horizontal scale, 1 in. = 2 miles; vertical distances not to scale.

mechanism for the transmission of the compressive forces can be suggested. The close spacing of the ridges, their parallelism and symmetrical cross section are against the idea that they were caused by faulting in the bedrock, and I would suggest that they reflect a buried topography, consisting of regular, steep ridges in some places, and more rounded hills in others. The proximity of the Grampians, and the presence of an outlying patch of Grampians sandstones at Mt. Arapiles, indicates that perhaps the regular and parallel surface ridges overlie buried strike ridges of Grampians sandstones, and that the sharp curvature to the west of the Lawloit Range reflects the presence of a buried "nose" of a pitching fold in these rocks. The trend of the ridges is parallel to the general strike in the Grampians, and also to the ridge running southwards from Mt. Arapiles.

Major Topographic Features of the Mallee.

Major topographic features in a region such as north-western Victoria, where a cover of relatively soft Cainozoic rocks overlies a resistant basement complex, can be formed in several ways, the chief of which are (1) faulting and folding due to diastrophic forces acting on the covering rocks themselves, (2) by movements in the basement complex which are transmitted to the overlying strata, or (3) by differential compaction, which causes buried topographic features to be reflected in the rocks that cover them. In all these instances the surface topography is paralleled to some extent by the structures of the rocks covering the basement complex—structural anticlines are ridges at the surface, and so on. On the other hand, topographic features due to erosion are not directly reflected in the structures of the underlying rocks. Thus, in interpreting the topography of the Mallee, it is first of all necessary to discover how far surface features are represented in the structures of the Cainozoic rocks of the ancient Murray Gulf.

The only portion of the Mallee where the Cainozoic geology is known in sufficient detail for our present purposes is in the northern portion of Co. Weeah, where the artesian and sub-artesian water in the Miocene limestones is tapped by numerous bores. In boring for water in the Mallee, the bores are usually carried down to a particular geological horizon near the top of the Miocene limestones. The bore records are therefore susceptible of geological interpretation in a broad way, and sections along the lines AB, CD, EF, and GH in fig. 2 have been constructed on the assumption that the figure for "depth to fresh water struck," given for each bore (see Kenyon, 1914), indicates the depth to a particular geological horizon. This method was suggested to me by Mr. McNab, and Chapman's interpretation of the Murrayville bores indicates

that it is likely to be sufficiently accurate to give some idea of the geological structure, though I am informed by Mr. A. S. Kenyon that the same bed is not tapped in each bore. In addition, a geological section (fig. 4), based on the data given by Chapman (1916) and on unpublished sections by Mr. A. S. Kenyon that were kindly placed at my disposal by Mr. L. R. East, Chairman of the State Rivers and Water Supply Commission, has been drawn along the line of bores studied by Chapman. The structure revealed in this section is paralleled in those along the lines above referred to, indicating the validity of the method used in their construction.

It is immediately clear from the sections that the surface features in northern Weeah are reflected in the structure of the Cainozoic rocks. In particular, the rise to the high area near the South Australian border, south of Panitya, is well brought out (see fig. 4). Howchin (1929) has already recognized the

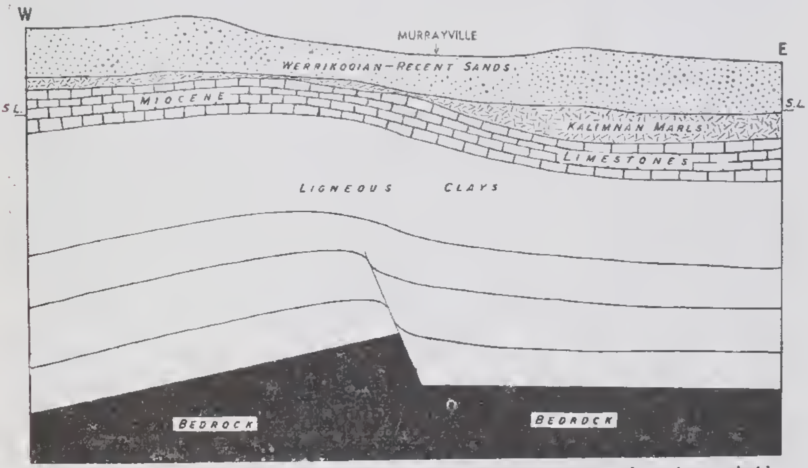

Fig. 4.—Geological section in the north of Co. Weeah, illustrating the probable relationship of warping in the Cainozoic rocks to faulting in the bedrock. Nature of bedrock unknown. Vertical scale for upper part of section, 1 inch = 600 feet; horizontal scale, 1 inch = 5 miles. Total thickness of Cainozoic rocks diagrammatic.

tectonic origin of the corresponding area of high land around Pinnaroo in South Australia, basing his conclusions on the elevation of the superficial alluvial deposits, which must have been deposited when the area was at a lower level, and have been raised to their present position by recent earth movements. Howchin's work, moreover, makes it clear that the structural features were not developed as a result of differential compaction in the Tertiaries over bedrock ridges and troughs, for this process would have operated during the deposition of these rocks. It would have caused the development of a ridge in the Miocene limestones and Kalimnan marls, which would have prevented the deposition of the superficial Pleistocene and Recent alluvium that actually occurs on the summit of the high land.

The marked warp on the north-east side of the high area south of Panitya can be traced from the bore records, and is shown in fig. 2 as F1. In South Australia the high land west of this structure can be outlined by form lines constructed from railway elevations (see Insert, fig. 2). It is also shown in Jack's sections (1930). The high land trends north-westerly towards the Great Pyap Bend in the Murray, and appears to have been responsible for turning the river towards the north-west at the bend. In Victoria such elevations as are available in the Big "Desert" indicate a continuation of the structural line to the south-east, with low land on the eastern side, and it may continue further south, for the land west of the Wimmera River is, on the average, higher in elevation than that on the east. West of Dimboola the Wimmera turns northwards away from the high land which blocks its exit to the west. The probable origin of the warping in the Cainozoic rocks near Murrayville is suggested in fig. 4. As noted in connection with the Lowan ridges, it is difficult to conceive a mechanism capable of folding these rocks by lateral compression, and since, as above noted, differential compaction over buried bedrock is excluded owing to the existence of fluviatile and lacustrine deposits on the up-warped western side, it appears to be most probable that the warp at the surface reflects a fault in the bedrock beneath the Cainozoic cover. The greater thickness of Kalimnan marls on the down-warped side indicates that the structure was partially formed before these rocks were laid down, but was completely covered by them, and then subjected to a later movement, warping the Kalimnan and the overlying, younger deposits.

It is still possible that other factors may have operated to produce the ridges and troughs in other parts of the Mallee and in the Wimmera. A clue to the possible effects of differential compaction over buried bedrock ridges, for instance, can be obtained by noting the relationship of the ridges of the plains to spurs running out from the highlands. Two spurs that are particularly instructive are, firstly, that on which Mt. Jeffcott, near Wooroonook, is situated, and that between Donald and Buckrabanyule. The latter is sharply truncated in the north at the 400-ft. contour, and the former at the 350-ft. contour. The Mt. Jeffcott ridge is on the same trend line as the summit of the Tyrrell Ridge, north-west of Birchip, but this latter ridge swings to the south and passes to the west of Birchip, so that it appears to be unrelated to the Mt. Jeffcott ridge. Furthermore, those inliers of bedrock that occur in the plains, as in Wycheproof and south of Lake Boga township, are not situated on the main ridges. Mt. Wycheproof, a low granitic hill, rises like an island from the surrounding plains, and the Lake Boga granite occurs as a low hill, indistinguishable topographically from those surrounding it, which are presumably composed of Cainozoic sediments. The summit of the Cannie Ridge lies well to the

west of this granite outcrop. Near Glenorchy and also south of Mysia, small hills of bedrock rise from the plains. Here again the bedrock outcrops are unrelated to the main ridges. It would appear, therefore, that differential compaction of the Tertiaries over bedrock ridges and valleys has not been an important factor in determining the major topographic features of the north-western plains, although it may have affected the topography in Co. Lowan, as above noted.

It is significant that the ridges, troughs, and basins in the Mallee are, with the exception of the complex ridges and valleys in Co. Karkarooc, large-scale features. The ridges are of the order of eight miles across, and the Tyrrell Basin is approximately thirty miles from east to west and fifty miles from north to south. It is clear from this fact alone that erosion is inadequate to explain them. As indicated above, lateral compression is also difficult to invoke, but it may be applicable to the Karkarooc ridges, where compressive forces possibly developed as a result to squeezing between F1 (see fig. 2) and a possible fault or major warp beneath the Tyrrell Ridge.

Most of the major ridges are, I believe, due to warping and faulting in the basement complex. Such movements are known to have occurred in connection with the warping in Co. Dundas, and also in the Echuca district (Harris, 1938), near Murrayville as described above, and near Casterton. At the latter locality, a N.W.-S.E. trending fault (F2, fig. 2) exposes Miocene limestones on the scarp. This fault is a continuation of the northern fault (F2) shown by Fenner (1931, p. 60) in south-eastern South Australia. Warping and faulting have also occurred in the Western Highlands. Where the cover of Cainozoic rocks is thin, an indication of upwarping would be given by the stripping off of this cover and the exposure of the bedrock as a major "spur" running north from the Highlands. The Gladstone "spur" (Gregory, 1903), which extends north from Wedderburne (fig. 2), appears to represent such an upwarped region. The low granitic plateau which surrounds the higher slopes of Mt. Korong may be regarded as a stream-planed pediment developed by laterally eroding streams before uplift occurred. Upon elevation of the region this erosion surface would be preserved on the resistant granites, but removed where it was cut in the surrounding metamorphic and sedimentary rocks. It is notable that the Cannie Ridge and the Gredgwin Ridge are in line with the Gladstone "Spur," and they probably represent similar and perhaps related upwarpings in the bedrock.

The Evolution of the Drainage System.

The present drainage system of the area is quite distinct from the normal arrangement of streams in regions of pluvial climate. In the Highlands to the south the stream pattern is dendritic, but

where the streams enter their plain tracts they develop anastamosing anabranches, and some of the main north-flowing streams, e.g., the Yarriambiac Creek, Dunmunkle Creek, Tyrrell Creek, and Lalbert Creek, are effluents from the Wimmera and the Avoca Rivers. After taking their origin from the parent stream, either by a single channel or a number of minor channels, these effluents receive no tributaries, and, owing to evaporation and downward percolation, gradually diminish in flow to the north. With this diminution in volume downstream, the flow ultimately becomes so reduced that small topographic basins into which the streams flow are sufficient to hold the water normally available. Thus, all the streams flowing to the north, except the Dunmunkle Creek, terminate in shallow lakes.

The Glenelg System.

In his paper on the Glenelg, Fenner has suggested that the present course of this stream above Dergholm is the result of numerous river captures, whereby the headwaters of the former Glenelg captured streams which previously ran north from the divide in Co. Dundas, leaving at Brim Springs (Brimpaen Station) and Fulham, sharp elbows of capture. The topographic map lends strong support to the idea that a stream formerly ran northwards from the elbow at Fulham, and that another north-flowing stream occupied the valley in which the White Lakes are now situated. Near Fulham a broad valley extends northward from the elbow in the Glenelg, as shown by the 550-ft. contour. In the valley are numerous swamps (e.g., Barton Swamp), and its western edge falls steeply away from the plains around Kanagulk in a manner reminiscent of the Wimmera valley at Horsham. Below the elbow at Fulham, and also for some miles above it, the Glenelg is incised below the level of the north-trending valley. The valley containing the White Lake has a similar relation to that of the Glenelg. These relationships strongly suggest that river capture has taken place, but the present condition may also have arisen by other means.

It is possible that these dry valleys were formerly occupied by effluents from the Glenelg, before rejuvenation caused that stream to cut down to such a depth that effluents could not leave it. The former condition may have resembled that of the Wimmera at present. This stream, after leaving the Highlands, flows to the west and gives off the Dunmunkle and Yarriambiac Creeks. Rejuvenation of such a system would cause the main stream to cut down much more rapidly than the effluents, which would ultimately be left as dry valleys, when they could no longer be fed by the waters of the main streams during floods.

A difficulty in interpreting the changes as due to capture is to account for the headward erosion of the Glenelg around the western end of the Dundas Highlands, for the streams north

of the divide would have been, at least in their headwater regions, actively eroding, and would have cut down below the level of the headwaters of the streams flowing south. It is conceivable that the Glenelg flowed, *a priori,* from the north side of the Dundas divide, and it may then either have enlarged its former headwater region by capture, or have lost effluents in the manner outlined above.

At Brim Springs, where Fenner again postulates river capture, neither of the above processes appears to me to have taken place. The Glenelg, for some distance above and below the bend at Brim Springs, follows a very shallow, wide, swampy course which during dry weather is so unlike the valley of a stream that it can be crossed unwittingly. There is no gorge below the elbow, which indicates that capture has not occurred. A possibility is that, with such a weak stream, a slight warp across its course may have diverted it from a northerly course through the gap at Brim Springs and turned it south-westerly. This would also explain the swampy nature of this reach of the river, but on the actual divide at Brim Springs, solid Tertiary sandstone occurs, and river gravels, sands, and silts are absent. Thus, it appears more probable that no stream has flowed north through the Brim Springs gap since the initiation of the present drainage system, and that, with further aggradation in the swampy Glenelg at this locality, the river might even raise its bed the necessary 40 feet to overtop the low divide between it and the northern streams, and so flow out to the north.

The Wimmera.

Before the above changes in the Glenelg system took place, the Wimmera must have received at least one, and probably two, important tributaries from the south-west. The valley leading from the Glenelg at Fulham trends towards the Wimmera, and the White Lakes valley leads towards the lakes around Mitre, whence the waters of the former stream could have reached the Wimmera below Natimuk. Thus, the lower reaches of the Wimmera must have shrunk considerably in volume as a result of drainage modification, apart from any possible effects of climatic desiccation. It is interesting to note, therefore, that north of Pine Plains, which is the furthest north that the Wimmera waters have been known to reach (Kenyon, 1914-15), such topographic data as are available indicate a continuation of the main valley towards the north, with a lateral outlet south of Walpeup. The main valley leads north-westerly into a basin north of the railway line between Underbool and Cowangie, which is cut off from outlet to the west and north by higher land. As shown above, this high land is of quite recent tectonic origin, and Howchin has shown that corresponding high land around Pinnaroo was formerly occupied by lakes and traversed by rivers. To the north and north-east,

outlets from the extension of the Wimmera valley are also indicated by areas below 150 feet or even 100 feet, as at Rocket Lake and the Raak Plain. Between these low areas and the Murray, however, the lowest levels are above 100 feet, and if a former outlet of Wimmera waters took place through the Hattah Lakes or near Nowingi, earth movements must subsequently have reversed the slopes.

Copi Deposits.

In connection with the former condition of the north-western Mallee, the distribution of gypsum (copi) deposits is instructive (see maps, figs. 1 and 2). It will be noted that the main areas of copi are situated in the existing topographic basins. In many of these areas copi is not now forming. The restriction of copi deposits, in the main, to topographic basins, and the fact that it is forming to-day only in salt lakes, as in the Raak Basin and Lake Tyrrell, indicates that the copi deposits in Co. Weeah and Co. Millewa were laid down in former lakes. Chapman (1936) has demonstrated the existence of lacustrine ostracodal limestone in one of the main areas where copi occurs, around Bennett's Tank and Cudmore's Tank in north-western Millewa. Thus, there can be little doubt that lakes formerly existed in the main topographic basins in the far north-west of Victoria. In South Australia it has already been shown that uplift west of Overland Corner caused a lake system to develop upstream from the fault (Tate, 1885; Howchin, 1929). The former lakes of the north-west of Victoria are also undoubtedly due to modifications of former courses of the Wimmera and Murray, resulting from earth movements.

An idea of the conditions that existed in these lake basins can be obtained by analogy with similar basins in regions that are still supplied with water, e.g., the Tyrrell Basin. Here, radial centripetal consequent streams, the Tyrrell Creek and Lalbert Creek, both effluents of the Avoca which skirts the edge of the basin, flow during floods towards the centre of the basin, and supply water to the shallow lakes situated there. The bed of Lake Tyrrell, which is only a foot or so deep in normal seasons, is composed of fine mud in which gypsum crystals are embedded. Salt is also obtained from the lake during the dry season.

The lake itself is bounded by steep banks, 20 or 30 feet high on the western side, and it is possible that the actual lake basin was initiated as a result of the solution of underlying beds of gypsum, deposited during an earlier stage of the infilling of the Murray Basin. Evidence for the presence of soluble beds beneath the surface is afforded by sink holes that occur near the north-east side of the lake, and by the record of 233 feet of gypsum in the Marlbed bore (Jack *et alia*, 1897). Of recent years, deep gullying has occurred on the slopes leading to the

lake, and in these the sediments exposed are gypseous sands, well bedded and even laminated in places, which are evidently lacustrine deposits. These now have a gentle dip towards the lake, indicating that the present lake basin is a sagged area. The suggestion is that the now dry copi basins in the far north-west formerly resembled the Tyrrell Basin, but are now dry because of the reduction in the flow of the Wimmera consequent upon the capture of some of its tributaries by the Glenelg, and of the drainage of lakes formerly filled by Murray waters, as that stream cut its gorge below Overland Corner. Increasing aridity is a possible further contributing factor.

The Yarriambiac Creek.

This stream, which is an effluent of the Wimmera, presents some peculiar features. After leaving the Wimmera in a normal fashion as an overflow channel on a flood plain, it passes into higher country to the south, and at Jung enters a trough bounded on either side by a ridge. The ridge on the west rises to 500 feet at Jung township. This condition is quite abnormal for an effluent stream, which normally should flow over a flood plain throughout its whole course. A further notable feature of the Yarriambiac Creek is its straightness. Both these peculiarities indicate that below Jung the Yarriambiac is probably a longitudinal consequent stream occupying a synclinal valley, and bounded on either side by anticlines. South of Jung the ends of the ridges have been truncated by lateral plantation due to the swinging of the Wimmera over its meander belt.

The Loam and Sand Ridges.

The Lake-shore Loam Ridges.

Although all the Victorian streams in the area under consideration, except the Dunmunkle Creek, terminate in shallow lakes, the most complex lake system is that developed on the flood plains of the Loddon, Avoca, and Murray Rivers, between Boort, Kerang, and Swan Hill. Some of the lakes in this district are fed by the Murray anabranches, some by the Avoca, others by the Loddon. In some there is both an inlet and an outlet; others, again, have neither.

A feature of these lakes is that each possesses on its eastern side a loam ridge, crescentic in plan and with a smooth, even surface whose elevation decreases towards its northern and southern ends. There can be little doubt that the origin of these ridges is in some way bound up with the action of the westerly winds, which are dominant in causing sand drift in the Mallee. While the formation of littoral sand dunes around lake shores is readily understandable, especially in the case of lakes with sandy floors that are exposed during dry seasons, the crescentic loam ridges are not so susceptible of ready interpretation.

Sand or loam ridges occur on the eastern sides of practically every lake and swamp in far western and northern Victoria. Those of the Corop district have recently been described by Harris (1938), who refers to their occurrence around Lake Cooper and the nearby swamps. All the Mallee and Wimmera lakes, and most of the swamps, are supplied with one or more ridges on their eastern sides, and the Myarring Swamp in Co. Normanby has such a ridge. Furthermore, in the volcanic plains of the Western District, Lakes Colongulac and Kariah have "dunes" of black loam on their south-eastern sides. Normal littoral sand dunes occur on the eastern shores of Lake Hindmarsh.

The littoral sand dunes are clearly due to the action of westerly winds on the sands exposed on the lake floors during dry seasons. The form of the resulting dunes differs from that of typical dunes of sandy deserts and marine coasts chiefly in the rounding of the slopes, for sand-fall slopes in which the sand is at its angle of rest are not found around the lake shores.

In contrast with these sand dunes, however, the crescentic loam ridges have a very regular form (see Fig. 5B), and are composed practically entirely of extremely fine particles resembling true aeolian loess. Like the loess, also, they contain concretions of calcium carbonate. A mechanical analysis of loam from the ridge on the eastern side of Kangaroo Lake, kindly made for me by Mr. G. Baker, showed that the sand fraction (0.5 mm. and over) is only 6.4 per cent., the silt fraction 78.3 per cent., and the proportion of material soluble in hydrochloric acid 15.3 per cent. The regular form of the ridges indicates that it is highly improbable that they should have accumulated like dunes by the arrest of detritus moving under aeolian traction or saltation from the lake floors during dry periods. Such a process of drift of detritus typically results in hummocky sand accumulations, though the regularity of barchans is comparable with that of the loam ridges. Barchans, however, are mobile, and the loam ridges fixed in position. The chief question that arises concerning their origin is, did they form during times when the lakes were dry or when they were full? When the lakes are dry the lake floors would be a source of supply of fine dust which would undoubtedly be transported eastwards by the dominant westerly winds. The material of the lake floors, however, is so fine grained that much of it would undoubtedly be lifted into the air by strong winds, and it is unlikely that it would be re-deposited on the lake shores, for there is no particular feature there that would cause dust to be deposited.

On the other hand, when there is water in the lakes in summer, strong westerly, north-westerly, or south-westerly winds would often carry large supplies of dust from outside the area or from the Murray flood plain. These winds would

also whip up spray from the lakes, and this spray would capture dust from the air and carry it down in falling on the eastern shores of the lakes. Thus, in time a ridge would be built up. This hypothesis explains the smooth, regular contours of the ridges, the fact that they are composed of fine loam with a very small proportion of sand, and their restriction to the shores of lakes.

In regard to the necessity for the presence of water in the lakes in forming the ridges, an area in the Parish of Benjeroop is instructive (fig. 5A). There, two small lakes, now salt, occupy basins that were clearly formerly occupied by larger lakes, fed by Loddon anabranches. Loam ridges were formed on the eastern shores of these former lakes, but as the area of the lakes has shrunk, a process that appears to have gone on in two stages, smaller ridges were formed on the shores of the shrunken lake remnants. Each ridge follows the edge of the lake on whose shores it formed. Thus, it is clear that it is the presence of water which is the controlling factor in their formation, and not the existence of a dry lake bed. The salinity of the lake waters would also aid in the building of the ridges, for the salts deposited from the evaporation of spray droplets would be hygroscopic, and thus tend to retain dust blown along the surface of the ground. This hypothesis would explain the fact that the ridges around lakes that have been kept artificially full for years are still, in many instances, perfectly preserved, except for gullying due to over-grazing or trenching. Some lakes, e.g., Kangaroo Lake and Lake Charm, have a series of ridges on their shores. It appears that perhaps owing to tilting downwards to the west, or to siltation, these lakes have migrated westwards in the past, leaving a series of ridges behind.

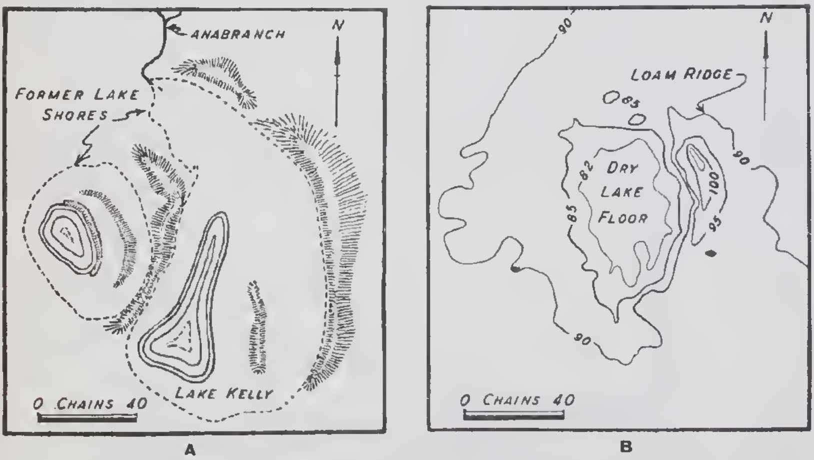

Fig. 5.—A. Map showing the relationship of loam ridges to lakes, Parish of Benjeroop. B. Contour map of a loam ridge and dry lake floor, Parish of Boort. Elevations in feet.

An interesting corollary of the above theory is that low loam ridges might be expected to occur along the eastern sides of the more permanent reaches of the streams in northern Victoria. Such loess-loam formations could be differentiated from natural levee banks by their restriction to the eastern sides of the streams. In the Parish of Benjeroop a well-marked meander of a Loddon anabranch possesses such a ridge, and I am informed by Mr. Rogerson, of the State Rivers and Water Supply Commission, that low loam mounds, used as kitchen middens by the aboriginals, occur along the Murray. As a result of subsequent changes in the stream channels, such loess-loam mounds would be left on the flood plain in an apparently haphazard way. Harris (1938) has described loam ridges, older than the present Murray course, in the Echuca district, and it may be that these were formed in the manner suggested above.

The Sand Ridges.

A characteristic of those parts of the Mallee that are elevated above the level of possible flooding by rivers, or by the water of lakes or swamps, is the presence of sand ridges similar in many respects to those described by Madigan (1936) in the desert areas of Central Australia. Over large areas the ridges are sub-parallel, with a general trend a little north of east and north of west, but in some of the "desert" areas they are irregular, and are referred to by surveyors as "jumbled." The average distance apart of the parallel ridges between Ouyen and Red Cliffs is about 16 chains, and the highest ridges in this district are 40 feet above the neighbouring troughs, though the average elevation is only about 20 feet. In areas such as the Little and Big "Deserts" and near Hattah, where the surface sand is loose and friable, sand drift occurs even in virgin scrub-covered country. In these areas the sand is not lifted far above the ground by strong winds, but there is a general superficial drift among the scrub.

In the Big Desert the southern slopes of the ridges are the steeper, and this is also true of the ridges between Ouyen and Hattah (see Fig. 6). Madigan has noted that the Central Australian ridges are asymmetrical, a feature he ascribes

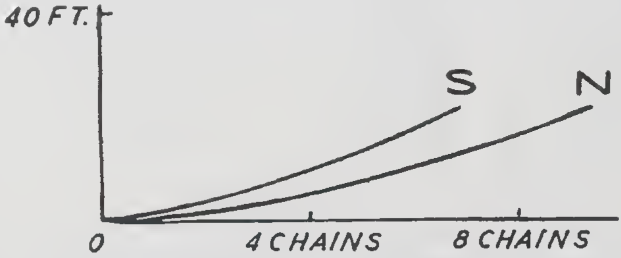

Fig. 6.—Comparison of the average slopes of northern (N) and southern (S) sides of sand ridges, north of Ouyen.

to the action of winds of secondary importance, coming from a quarter different from dominant winds that cause the ridges to develop. The persistence of these sand ridges for long distances, and their regular spacing (see fig. 7), are still unexplained. It is, however, a matter of common knowledge that the main direction of sand drift in the Mallee is from west to east, and there is no doubt that the sand ridges are longitudinal and not transverse to the drift-producing winds.

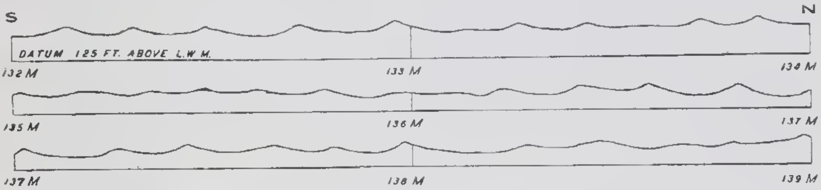

Fig. 7.—Cross-sections of sand ridges between Ouyen and Hattah. Horizontal scale, 1 inch = ½ mile; vertical scale, 1 inch = 500 feet. For distances from Melbourne add 154 miles 63 chains to local mileages shown.

Evidence of the permanence of the ridges is afforded by their structure, as revealed in railway sections between Ouyen and Hattah. In a ridge at the 290-mile post on the Calder Highway, three hard calcareous "travertine" horizons occur with intervening sandy layers. The "travertine" bands are approximately parallel to the surface slopes of the ridge. In a ridge at 290¼ miles, two such travertine bands are visible (Pl. xxiv., fig. 2). Mineralogical analyses of the various hard and soft layers in this latter ridge have been kindly supplied to me by Mr. G. Baker, M.Sc. These show that quartz, which is the chief mineral component of all the layers, is accompanied also by andalusite, ilmenite, leucoxene, magnetite, rutile, sillimanite, tourmaline, and zircon. In the sandy layers A, B, C, and D (Pl. xxiv, fig. 2), biotite is also present, but this mineral is absent from the calcareous bands. Chlorite, which occurs in C, and hornblende, which is rare in A, C, and D, are also absent from the calcareous layers. The latter, too, contain very fine dust which is present at most in traces in the sands. It would appear that these fine particles have been washed from the sands and "fixed" in the calcareous layers, in which the calcareous cement has been chemically deposited between the sand grains, forcing them apart. There can be little doubt that the hard calcareous bands are soil horizons, the upper one being that now in process of formation. As no known pedological process is capable of developing superimposed calcareous horizons from an initial uniform rock mass, it appears to be reasonably certain that the lower horizons are buried soils. This indicates that the ridges have been situated in their present positions over a long period, and, furthermore, that they have grown in size intermittently by the addition of further supplies of sand, the process taking place in three stages. It is most probable that these three stages

of growth are to be correlated with periods of aridity which alternated with moister periods, when the soil horizons were formed and the movement of sand was inhibited by vegetation or by closing down of the source of supply. The immediate past was, if the above interpretation be correct, a period of relatively high rainfall. Evidence from other parts of Victoria to some extent supports this. Thus, between Mordialloc and Brighton, fixed sand ridges occur, which are not beach ridges formed during the uplift of the coastal plain, but are directly due to former aeolian sand drift, which has now ceased.

Abbott's studies of the copi deposits in the northern Mallee also indicate that there have been climatic changes during the recent past. Sections of the copi hills, which rise above the level copi plains near Cowangi, show that pure powdery copi typically overlies impure sandy copi (see fig. 8). It is probable

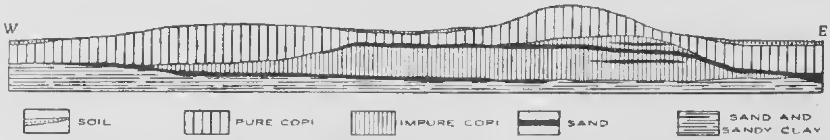

Fig. 8.—Cross-section of copi deposits, east of Cowangie; Allotment 7, Parish of Tutye. Vertical scale, 1 inch = 45 feet; horizontal scale, 1 inch = 150 feet. After S. B. Abbot.

that these copi hills are the weathered remains of gypsum dunes such as have been described in South Australia by Jack (1930). The impure copi, which invariably contains sand lenticles, is composed of granular "seed" gypsum, often showing aeolian cross bedding. If, as Jack suggests, the powdery copi at the surface is formed by the weathering of the "seed" gypsum, then it is likely that the climatic or drainage conditions in the northern Mallee have changed since the impure copi was laid down and subsequently blown up into gypsum dunes, for this process is not now operative in the copi districts of Co. Weeah. It is probable that the present and the immediate past, during which sand drift has been arrested in many places (except where the conditions have been changed by the activities of man), and solution and re-deposition of the dunes of "seed" gypsum has developed powdery copi at the surface, were wetter than earlier periods.

Relation of Sand Ridges to Streams.

Below Lake Albacutya, the Outlet Creek makes its way between a well-developed series of east-west sand ridges. For long periods the Outlet Creek is dry, but it is said to carry water on an average about once every twenty years. The pattern of the drainage of the creek through the ridges is remarkable. Effluents run off to the east and west, feeding basins among the ridges, which become ephemeral lakes such as Lake Brambruck. These lakes are analagous to, though much smaller than, the

bajirs described by Sven Hedin, which are formed by the flooding of the Tarim, in Central Asia, among the sand ridges that cross its course.

The development of a drainage line through the ridges in this fashion indicates two things: firstly, the drift of sand is not sufficiently rapid to effectively block the stream course during its dry periods, and secondly, the ridges probably developed before the stream began to cross them; otherwise they would not have developed on the eastern side of the stream, if the supply of sand is from the west. Thus, again, the evidence indicates that at the present time the sand drift is not so active as it once was, and that the present is a time of relatively high rainfall.

Physiographic Divisions of the North-Western Plains.

The Murray Valley.

The three major physiographic divisions of the area are the Murray Valley, the Mallee, and the Wimmera. The Murray Valley is the flood plain of the Murray, which is subject to periodical inundations except where artificial levee banks have been constructed. As shown by Tate (1895), Patton (1930), and Zimmer (1937), this region carries a characteristic association of Red Gum and Grey Box, both of which require flooding by river waters for their growth. Insufficient is known of the physiographic history of the Murray in Victoria to elucidate the details of the Murray Valley. It is notable, however, that the river is deflected northwards when it meets the Cannie Ridge at Swan Hill, and that it is encroaching on the fixed sand ridges near Wood Wood and elsewhere. It keeps close to the northern end of the Tyrrell Ridge at Robinvale, but is deflected northwards again at the Hattah Lakes, where it is evident that marked drainage modifications have occurred, and flows close to the eastern edge of the Red Cliffs Ridge to Mildura. It is only near the Hattah Lakes, however, that there is any indication of recent changes in the Murray's course, such as may have resulted from tectonic movements. In the other cases the ridges appear to be older than the river, which is encroaching on them.

The Mallee.

The Victorian Mallee is, in general, an areic region (Fenner, 1931). Over practically the whole area aeolian sand ridges occur. The major topographic features are ridges and troughs with a trend varying from north-south to north-west–south-east, and also broad basins. Floristically, it is characterized in part by an association consisting chiefly of stunted eucalyptus (Mallee scrub), together with Murray Pine and Belah which typically grow on the ridges (see Patton, 1930, and Kenyon, 1914-15).

In the south and east this association is replaced by the grasslands and Savannah woodlands of the Wimmera and the Northern District Plains.

Wood (1929) has stated that the southern boundary of the Mallee floral association follows the line of 20-in. winter rainfall (May–October). On his map he shows a 20-in. isohyet, which is actually the average annual figure and not that for May–October. Data recently published by the Commonwealth Bureau of Meteorology (Watt, 1937) show that the 20-in. average annual isohyet corresponds approximately to the 12-in. isohyet for May–October, but, in any case, this line is too far south to be acceptable as the southern boundary of the Mallee. Patton (1929) has already shown that it is the 15-in. annual average isohyet which forms the approximate southern boundary of the Mallee in Victoria. Many factors other than rainfall are, however, involved, and the combined effects of these is reflected in the vegetation, which may therefore be used to define the boundary for physiographic purposes.

On the topographic map (fig. 1) the boundary of Mallee land, as determined from an examination of the plant communities, is shown. This boundary was surveyed many years ago, and is shown on the standard base map of the Lands Department, on a scale of 8 miles to 1 inch. The boundary reveals an interesting relationship to topography. Along the river valleys, for instance, tongues of the Wimmera type of country, or of Redgum and Box associations, extend northwards into the Mallee. On the other hand, on the ridges the Mallee boundary swings southwards into regions of presumably higher rainfall than the main Mallee area. In Co. Lowan the ridges are composed of sandstone which does not appear in the valleys, where soils of the Wimmera type occur. These sandstone ridges yield an extremely loose sandy soil, which clearly is the determining factor in vegetation control. The Little "Desert," which is often classed as Mallee, actually carries *Banksia, Casuarina, Acacia, Leptospermum,* and *Xanthorrhea,* but not typical Mallee scrub eucalypts (d'Alton, 1913). This association is somewhat similar to that found on areas of Tertiary sands in other parts of the State, e.g., on the flanks of the Otway Ranges.

It would appear that the chief factors involved in the distinction between the Mallee and the country south and east of it are precipitation, evaporation, rock type, porosity of the superficial deposits, drainage away from high areas, and supply of water from streams that rise in regions of higher rainfall.

The Wimmera.

For physiographic purposes, I propose to term the region south of the Mallee and north of the Western Highlands the "Wimmera." This region is characterized by extensive flood

plain deposits of river alluvium, both Recent and older; by flowing streams, many of which are aggrading and have anastamosing courses or give off anabranches, and by an average annual rainfall between 15 and 22 inches. As remarked in the introduction, it is convenient to regard the Loddon River as the eastern boundary of the Wimmera. Both the Wimmera and the Mallee exhibit well-defined topographic ridges, troughs, and basins, but such features are not found further east in the Northern District Plains, except where bedrock outcrops. Also, the Loddon joins the Murray, whereas the streams of the Wimmera do not. In Co. Lowan the boundary of the Wimmera may be taken as the northern limit of dissection by tributaries to the Glenelg, and by the Mosquito Creek and neighbouring streams, that flow into South Australia.

Summary and Conclusions.

The history of the ancient Murray Gulf may be summarized as follows:—

1. Sagging in post-Cretaceous times was accompanied by the deposition of a series of continental, estuarine, and marine ligneous clays, lignites, sands, and gravels, mainly Oligocene in age.

2. This sagging was accompanied by a general rise of sea level in southern Australia during Miocene and Lower Pliocene times, during which marine limestones (chiefly) were deposited.

3. By Werrikooian (Upper Pliocene) times the sea coast had retreated to the south-eastern portions of the Gulf, continental and estuarine conditions prevailing in the north-east and north.

4. Positive movements of elevation during Pleistocene and Recent times were accompanied by faulting and warping. The sea coast retreated to its present position, leaving behind the old beach ridges and littoral sands that extend from Narracoorte to the coast in South Australia and south-western Victoria.

5. On the Pleistocene land surface, streams fed by a plentiful rainfall deposited a veneer of sands and silts over the older beds. The Murray may in early Pleistocene times have entered the sea near Tintinarra, its course being through the Murrayville district (see Howchin, 1929).

6. The Pleistocene and Recent earth movements above mentioned caused extensive changes in the course of the Murray, as outlined in the text. Lakes were formed upstream from the Pyap Bend and Overland Corner, and in these lakes, or their shrunken remnants, copi and ostracodal limestones were deposited.

7. The rainfall decreased after the Pleistocene, but during Recent times there have been relatively wetter and drier periods, the present and immediate past being relatively wet.

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FIG. 1.

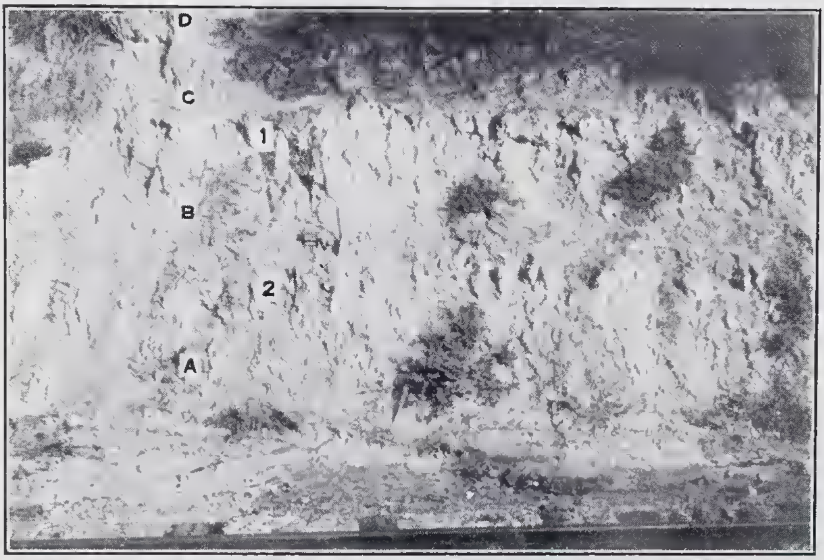

FIG. 2.

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Explanation of Plate XXIV.

Fig. 1.—The dissected plain in County Dundas, north of Coleraine.

Fig. 2.—Section across a sand ridge, north of Ouyen. A, B, C, sandy layers; D, superficial, loose sand; 1, upper calcareous layer; 2, lower calcareous layer.

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Cherry, Prof. T. M., B.A., Ph.D., University, Carlton, N.3 ..	1930
Clark, G. Lindesay, M.C., B.Sc., M.ME., c/o Gold Mines of Australia Ltd., P.O. Box 856K, Melbourne, C.1	1931
Cudmore, F. A., 12 Valley View-road, East Malvern, S.E.6 ..	1920

Davis, Captain John King, 35 Wills-street, Melbourne, C.1 1920
Dyason, E. C., B.Sc., B.M.E., 92 Queen-street, Melbourne, C.1 .. 1913
Edwards, A. B., B.Sc., Ph.D., D.I.C., Geology School, University, Carlton, N.3 1930
Esserman, N. A., B.Sc., A.Inst.P., Research Laboratories, Maribyrnong, W.3 1923
Gepp, Sir Herbert W., Box 1643, P.O., Melbourne 1926
Grice, J. Hugh, "Highfield," Lilydale 1938
Grimwade, W. Russell, B.Sc., 342 Flinders-lane, Melbourne, C.1 .. 1912
Hartung, Prof. E. J., D.Sc., University, Carlton, N.3 1923
Hills, E. S., M.Sc., Ph.D., Geology School, University, Carlton, N.3 1928
Jack, R. Lockhart, B.E., D.Sc., F.G.S., c/o Broken Hill Pty Ltd., 422 Little Collins-street, Melbourne, C.1 1931
James, A., B.A., D.Sc., 23 Bayview-crescent, Black Rock, S.9 .. 1917
Jones, Wood, Prof. F., D.Sc., M.B., B.S., M.R.C.S., L.R.C.P., F.R.S., F.Z.S., University, Manchester, England 1930
Jutson, J. T., B.Sc., LL.B., "Darlington," 9 Ivanhoe-parade, Ivanhoe, N.21 1902
Keble, R. A., National Museum, Melbourne, C.1 1911
Lang, P. S., B.Agr.Sc., School of Agriculture, University, N.3 .. 1938
Leeper, G. W., M.Sc., Chemistry School, University, Carlton, N.3 .. 1931
Lewis, J. M., D.D.Sc., "Whitethorns," Boundary-road, Burwood, E.13 1921
MacCallum, Prof. Peter, M.C., M.A., M.Sc., M.B., Ch.B., D.P.H., University, Carlton, N.3 1925
Michell, J. H., M.A., F.R.S., 52 Prospect Hill-road, Camberwell, E.6 1900
Millen, Senator J. D., 2 Collins-street, Melbourne, C.1 1920
Miller, E. Studley, 396 Flinders-lane, Melbourne, C.1 1921
Miller, Leo F., "Moonga," Power-avenue, Malvern, S.E.4 .. 1920
Mackinnon, J. C., Melbourne Club 1938
Morrison, P. Crosbie, M.Sc., 44-74 Flinders-street, C.1 1938
Newton, Sir Alan, M.B., M.S., F.R.C.S., 85 Spring-street, Melbourne, C.1 1931
Nicholas, Geo. R., 48 Lansell-road, Toorak, S.E.2 1934
Orr, Dr. R. Graeme, M.A., B.Ch., 621 Toorak-road, S.E.2 1935
Orr, Dr. W. F., 8 Collins-street, Melbourne, C.1 1932
Parr, W. J., 17 Bokhara-road, Caulfield, S.E.8 1927
Patton, R. T., D.Sc., M.F., Hartley-avenue, Caulfield, E.8 1922
Penfold, Dr. W. J., M.B., 53 Prospect Hill-road, Camberwell, E.6 .. 1923
Piesse, E. L., 43 Sackville-street, Kew, E.4 1921
Priestley, R. E., M.A., D.Sc., University, Birmingham 1935
Quayle, E. T., B.A., 27 Collins-street, Essendon, W.5 1920
Rae, F. J., B.A., B.Sc., B.Ag.Sc., Botanic Gardens, South Yarra, S.E.1 1927
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Rivett, Sir David, M.A., D.Sc., Council for Scientific and Industrial Research, 314 Albert-street, East Melbourne, C.2 1911
Rogers, J. Stanley, B.A., M.Sc., University, Carlton, N.3 1924

Sewell, Dr. S. V., 12 Collins-street, C.1 1936
Shephard, John, "Norwood," South-road, Brighton Beach, S.5 .. 1894
Singleton, F. A., M.Sc., University, Carlton, N.3 1917
Stillwell, F. L., D.Sc., 44 Elphin-grove, Hawthorn, E.2 1910
Summers, Associate Prof. H. S., D.Sc., University, Carlton, N.3 .. 1902
Thomas, Dr. D. J., M.D., 81 Collins-street, Melbourne, C.1 .. 1924
Tiegs, O. W., D.Sc., University, Carlton, N.3 1925
Turner, Professor J. S., M.A., Ph.D., University, Carlton, N.3 .. 1938
Vail, Lieut.-Col. L. E., 485 Bourke-street, Melbourne, C.1 .. 1939
Vasey, G. H., B.C.E., University, Carlton, N.3 1936
Wadham, Prof. S. M., M.A., Agr. Dip., University, Carlton, N.3 .. 1932
Wettenhall, Dr. Roland R., "Aberfeldie," 557 Toorak-road, S.E.2 1938
White, Dr. A. E. Rowden, 85 Spring-street, Melbourne 1938
Woodruff, Prof. H. A., M.R.C.S., L.R.C.P., M.R.C.V.S., University, Carlton, N.3 1913
Young, Prof. W. J., D.Sc., University, Carlton, N.3 1923

Country Members.

Blackburn, Maurice, M.Sc., Fisheries Section, C.S.I.R., Cronulla, N.S.W. 1936
Caddy, Dr. Arnold, "Chandpara," Tylden, Vic. 1924
Caldwell, J. J., Geological Survey Office, Bendigo, Vic. 1930
Cox, H. M. S., Wombat Park, Daylesford 1931
Crawford, W., Gisborne, Vic. 1920
Drevermann, A. C., Dookie Agricultural College, Dookie, Vic. .. 1914
Glaessner, M. F., Ph.D., c/o Australasian Petroleum Co., Port Moresby, Papua 1939
Harris, W. J., B.A., D.Sc., High School, Echuca, Vic. 1914
Hope, G. B., B.M.E., "Carrical," Hermitage-road, Newtown, Geelong, Vic. 1918
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Mackenzie, H. P., Engr. Commr., R.N. (Ret.), Trawalla, Vic. .. 1924
Mann, S. F., Caramut, Vic. 1922
Quayle, D. S., 33 Gent-street, Ballarat 1939
Ramsay, Urquhart, "Turkeith," Winchelsea 1938
Thomas, D. E., c/o Geological Survey, Mines Dept., C.2 .. 1929
Trebilcock, Captain R. E., M.C., Wellington-street, Kerang, Vic. .. 1921
White, R. A., B.Sc., School of Mines, Bendigo, Vic. 1918

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Baker, G., M.Sc., Geology Department, University, N.3 1935
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Bordeaux, E. F. J., D.V.Sc., B. ès L., Mangalore-street, Flemington, W.2 1913

Brazenor, C. W., National Museum, Russell-street, Melbourne, C.1	1931
Breidahl, H., M.Sc., M.B., B.S., 23 Chatsworth-avenue, North Brighton, S.5	1911
Broadhurst, E., M.Sc., 457 St. Kilda-road, Melbourne, S.C.2 ..	1930
Burhop, E. H. S., B.A., M.Sc., Ph.D., University, N.3	1936
Buchanan, Gwynneth, D.Sc., University, Carlton, N.3	1921
Butcher, A. D., 19 Regent-street, Preston, N.18	1936
Butler, L. S. G., 173 Barkly-street, St. Kilda, S.2	1929
Campbell, J. D., B.Sc., B.M.E., Llewellyn-street, Beaumaris, S.10	1932
Canavan, T., B.Sc., 14 Kerferd-road, Glen Iris, S.E.6	1936
Carter, A. A. C., "Fairholm," Threadneedle-street, Balwyn, E.8 ..	1927
Chapman, Mrs. F., Threadneedle-street, Balwyn, E.8	1930
Chapman, W. D., M.C.E., "Hellas," Stawell-street, Kew, E.4. ..	1927
Chapple, Rev. E. H., The Manse, Warrigal-road, Oakleigh, S.E.12 ..	1919
Clark, J., F.L.S., National Museum, Melbourne, C.1	1929
Clinton, H. F., Department of Agriculture, Public Offices, C.2 ..	1920
Collins, A. C., 3 Lawrence-street, Newtown, Geelong	1928
Colliver, F. S., 14 McCarron-parade, Essendon, W.5	1933
Condon, M. A., B.Sc., Williamstown Racecourse, W.17	1937
Cook, G. A., M.Sc., B.M.E., 58 Kooyongkoot-road, Hawthorn, E.2	1919
Cookson, Miss I. C., D.Sc., 154 Power-street, Hawthorn, E.2 ..	1916
Coulson, A., M.Sc., 42 Gawler-street, Portland	1929
Coulson, A. L., D.Sc., D.I.C., F.G.S., Geological Survey of India, 27 Chowringhee, Calcutta	1919
Cowen, Miss Margot E. H., B.Agr.Sc., 2 Leaburn-avenue, S.E.7 ..	1936
Crespin, Miss I., B.A., Department of the Interior, Canberra, F.C.T.	1919
Croll, I. C. H., 4 Derby-street, Camberwell, E.6	1934
Deane, Cedric, "Cloyne," State-street, Malvern, S.E.4	1923
Dewhurst, Miss Irene, B.Sc., 2 Pine-grove, McKinnon, S.E.14 ..	1936
Drummond, F. H., B.Sc., University, Carlton, N.3	1933
Easton, J. G., Mines Department, Melbourne	1938
Edwards, G. R., B.Sc., Box 31, Casterton	1937
Elford, F. G., B.Sc., B.Ed., Teachers' College, Carlton, N.3 ..	1929
Elford, H. S., B.E., c/o Tait Publishing Co., 349 Collins-street, Melbourne, C.1	1934
Fawcett, Miss Stella G. M., M.Sc., 49 Bunbury-street, Footscray, W.11	1937
Fenner, C., D.Sc., Education Department, Flinders-street, Adelaide, S.A.	1913
Ferguson, W. H., 37 Brinsley-road, E. Camberwell, E.6	1894
Finney, J. M., 131 King-street, Melbourne, C.1	1925
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Forster, H. C., B.Agr.Sc., Ph.D., 4 Eyre-street, Deepdene, E.8 ..	1938
Frostick, A. C., 9 Pentland-street, N. Williamstown, W.16	1933
Gabriel, C. J., 293 Victoria-street, Abbotsford, C.1	1922
Gill, Rev. Edmund D., B.A., B.D., 24 Thomas-street, Hampton, S.7	1938
Gladwell, R. A., 79 Cochrane-street, Elsternwick, S.4	1938
Gordon, Alan, B.Sc., c/o C.S.I.R., Yarra Bank-road, South Melbourne, S.C.4	1938

Grieve, Brian J., B.Sc., Ph.D., Botany School, University, N.3 .. 1929
Grieve, Mrs. B. J., Botany School, University, N.3 1936
Hanks, W., 7 Lake-grove, Coburg, N.14 1930
Hardy, A. D., 24 Studley-avenue, Kew, E.4 1903
Hauser, H. B., M.Sc., Geology School, University, Carlton, N.3 .. 1919
Head, W. C. E., North-street, Nathalia 1931
Heysen, Mrs. D., P.O. Box 10, Kalangadoo, South Australia .. 1935
Hoette, Miss Shirley, M.Sc., 23 Moorhouse-street, Armadale, S.E.3 1934
Holland, R. A., 126 Kooyong-road, Caulfield, S.E.7 1931
Holmes, Mrs. S. C. A., M.Sc., Ph.D., "Oakbank," Hampton-grove, Ewell, Surrey 1930
Holmes, W. M., M.A., B.Sc., Observatory, South Yarra, S.E.1 .. 1913
Honman, C. S., B.M.E., Melbourne Technical College, 134 Latrobe-street, C.1 1934
Jack, A. K., M.Sc., 49 Aroona-road, Caulfield, S.E.7 1913
Jacobson, R., M.Sc., Woodbine-grove, Chelsea 1937
Jessep, A. W., B.Sc., M.Ag.Sc., Dip. Ed., Horticultural Gardens, Burnley, E.1 1927
Jona, J. Leon, M.D., M.S., D.Sc., Lister House, 61 Collins-street, Melbourne, C.1 1914
Keartland, Miss B., M.Sc., 56 Canberra-street, Brunswick, N.10 .. 1919
Kilvington, T., M.Sc., Physiology Department, University, N.3 .. 1938
Lennox, Mrs. Gordon, M.Sc., c/o C.S.I.R., Box 109, Canberra City, Canberra, F.C.T. 1934
Lindsay, Miss Eder A., B.Agr.Sc., Agriculture School, University, N.3 1936
McCance, D., M.Sc., 144 Gatehouse-street, Parkville, N.2 1931
MacDonald, B. E., "The Heights," 127 Banksia-street, Heidelberg, N.22 1920
McIver, Miss Euphemia, M.Sc., Higher Elementary School, Rochester 1936
McLennan, Assoc. Prof. Ethel, D.Sc., University, Carlton, N.3 .. 1915
Melhuish, T. D'A., M.Sc., Mt. Frome Lime Co., Burrow-road, St. Peters, Sydney 1919
Moore, F. E., O.B.E., Chief Electrical Engineer's Branch, P.M.G.'s Department, Treasury Gardens, East Melbourne, C.2 1920
Morris, P. F., National Herbarium, South Yarra, S.E.1 1922
Newman, B. W., B.Sc., Meteorological Bureau, Sydney 1927
Nicholls, Miss A., B.Sc., 633 Inkerman-road, Caulfield, S.E.7 .. 1929
Nye, E. E., College of Pharmacy, 360 Swanston-street, Melbourne, C.1 1932
Nye, Rev. Edward, B.A., Wesley College, St. Kilda-road, Prahran, S.1 1934
Oke, C., 34 Bourke-street, Melbourne, C.1 1922
Osborne, N., c/o Island Exploration Co., Daru, Papua 1930
Paterson, Miss Helen T., 7 Glan Avon-road, Hawthorn, E.2 .. 1933
Petersen, Miss K., B.Sc., 56 Berkeley-street, Hawthorn, E.2 .. 1919
Prentice, H. J., B.Sc., 218 Esplanade West, Port Melbourne, S.C.1 1936
Pretty, R. B., M.Sc., Technical School, Wonthaggi, Vic. 1922
Raff, Miss J. W., M.Sc., F.R.E.S., University, Carlton, N.3 .. 1910
Rayment, Tarlton, Bath-street, Sandringham, S.8 1929
Richardson, Sidney C., 2 Geelong-road, Footscray, W.11 1923

Rosenthal, Newman H., B.A., B.Sc., 10 Oulton-street, Caulfield, S.E.7	1921
Rothberg, M., B.Agr.Sc., 1094 Lygon-street, N.4	1937
Sayce, E. L., B.Sc., A.Inst.P., Research Laboratories, Maribyrnong, W.3	1924
Scott, T. R., M.Sc., 7 Garden-street, Hawthorn, E.3	1934
Shaw, Dr. C. Gordon, 57 Clendon-road, Toorak, S.E.2	1931
Sherrard, Mrs. H. M., M.Sc., 43 Robertson-road, Centennial Park, N.S.W.	1918
Smith, J. A., 25 Collins-place, Melbourne, C.1	1905
Stach, L. W., M.Sc., c/o Australasian Petroleum Co., Port Moresby, Papua	1932
Stevenson, K. N., B.C.E., C.E., L.S., 27 Carnarvon-road, N. Caulfield, S.E.7	1938
Sutherland, Miss Jean L., M.Sc., Presbyterian Girls School, Glen Ormond, Adelaide, S.A.	1934
Thomas, L. A., B.Sc., c/o Council for Scientific and Industrial Research, Stanthorpe, Queensland	1930
Traill, J. C., B.A., B.C.E., 630 St. Kilda-road, Melbourne, S.C.3 ..	1903
Trüdinger, W., 27 Gerald-street, Murrumbeena, S.E.9	1918
Tubb, J. A., M.Sc., Fisheries Section, C.S.I.R., Cronulla, N.S.W. ..	1936
Vasey, A. J., B.Agr.Sc., "Westaways," Werribee	1937
Wilcock, A. A., B.Sc., B.Ed., 294 The Avenue, Parkville, N.2 ..	1934
Wilson, F. E., F.E.S., 22 Ferncroft-avenue, E. Malvern, S.E.5 ..	1921
Wilson, Major H. W., O.B.E., M.C., C. de G., B.Sc., 630 Inkerman-road, Caulfield, S.E.7	1923
Withers, R. B., M.Sc., Dip. Ed., University High School, Parkville, N.2	1926
Wood, E. J. F., M.Sc., B.A., Fisheries Section, C.S.I.R., Cronulla, N.S.W.	1935
Wood, Assoc. Prof. G. L., M.A., Litt. D., University, Carlton, N.3 ..	1933
Woodburn, Mrs. Fenton, 21 Bayview-crescent, Black Rock, S.9 ..	1930
Wunderly, J., D.D.Sc. (Melb.), 2 Collins-street, Melbourne, C.1 ..	1937

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